MATERIALS AND METHODS USED IN MARKING EXPERIMENTS IN FISHERY RESEARCH

by

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PREPARATION OF THIS PAPER

This is one of a series of manuals and other documents produced by the Fishery Resources and Environment Division to assist scientists at all levels concerned with marine research applied to fisheries. The present paper deals with the practical aspects of conducting marking experiments, e.g., choice of mark, methods of handling and marking animals, ways of assuring the reporting of marked animals recaptured by fisheries, etc. It complements a previous paper by the same author on the statistical methods of designing marking experiments and estimating population parameters from the results (Jones, R., 1976. The use of marking data in fish population analysis. FAO Fisheries Technical Paper, No. 153).

The manuscript was reviewed by W.H. Bayliff, G.H. Winters, W.H Lear and S. Kume, who offered a number of useful suggestions. Original illustrations and redrawings in the paper were done by A. Macdonald; reproductions appear with the kind permission of the publishers of the sources cited.

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1. NATURE OF A MARKING EXPERIMENT

1.1 What is meant by a "mark"?

A "mark" is anything external, or internal, or incorporated into the integument of an animal that can be used for recognition purposes. The word "tag" is usually reserved for identification marks that are attached externally or inserted internally. For example, a piece of plastic inserted into the integument or body cavity, or attached externally, is usually referred to as a "tag". A patch on the integument produced by a dye, a tattoo needle or a branding iron, on the other hand, is usually termed a "mark". Thus a tag is a mark, whereas a mark is not necessarily a tag. Some animals can be distinguished from others due to the presence of particular parasites or meristic characters. These natural forms of identification are normally referred to as "biological tags" or "biological marks".

Animals bearing marks constitute a group known as the "marked population". Animals that have not been marked, form the "unmarked population". One of the requirements of a good mark is that it should enable the individuals in the marked population to be distinguished from those in the unmarked population.

1.2 What is a marking experiment?

This is any experiment in which an animal is marked so that it can be distinguished subsequently from unmarked animals.

Experiments vary from those in which there are very large numbers of marked and unmarked animals to those in which there are very few. For example, a very large number of individuals may have to be marked if there is to be a high expectation of getting some returned by commercial fishermen. On the other hand, if the object of the experiment is to study the behaviour of a single individual carrying a particular kind of mark, such as a sonic tag, then it may be sufficient to mark only one animal at a time.

Typically, a mark-recapture experiment involves the following sequence of operations:

Capture of the animals to be marked

Handling and holding the animals during the marking operation

The marking process

The release of the marked animals

The subsequent recapture of the animals and the detection or recovery of the mark

Factors that may operate to reduce the likelihood of success are:

Mortality of marked individuals

Loss of marks through shedding or deterioration

Failure to detect or report marked animals during the recovery process.

1.3 Objectives of a marking experiment

There are a number of reasons for marking animals and the principal ones are listed below.

1.3.1 Investigations of movements

This is one of the commonest reasons for marking. The object is to release one or more marked animals at a known point (or points) and to learn something about their movements from the distribution of those animals that are subsequently recaptured.

1.3.2 Investigation of mixing between different stocks

This is a special case of 1.3.1 where the species is known to be distributed in the form of distinct populations or "stocks". Marking experiments provide one way of investigating whether such local groups are independent or not.

1.3.3 Estimation of mortality rates

The mortality rate of a group of marked individuals may be estimated. This can be done from the way in which the rate of recovery of marked individuals declines with time. For theoretical details of the techniques involved the reader is referred to Jackson (1939), Robson and Chapman (1961), Chapman and Robson (1960), Beverton and Holt (1956), Gulland (1955, 1969), Paulik (1963), Jolly (1965), Seber (1965) and Robson (1963).

1.3.4 Estimation of growth rates

The growth rate of marked individuals can be studied. This can be done by determining the change in body size of an individual from the time of liberation to the time of recovery.

1.3.5 Estimation of population size

Estimates of the ratio of marked/unmarked animals in a sample can be used to determine the size of the unmarked population. For theoretical details see Ricker (1958), Robson and Regier (1964), Davis (1964), Jolly (1965) and Seber (1965).

Cormack (1969) and Jones (1976) review these and other theoretical papers.

1.3.6 Investigation of ageing techniques

In most species, growth of the skeletal or other hard parts is associated with the formation of rings (e.g., the formation of rings on the scale of a fish). Such rings can be used for ageing, provided the rate of ring formation per unit time is known. One way of investigating this is to determine the number of rings produced during a known time period such as that between the release and subsequent recapture of a marked fish.

1.3.7 Value of hatchery stocking and transplantation

This is a special case of 1.3.3, i.e., marking can be used to determine the mortality rate of individuals reared in a hatchery or transplanted from one area to another.

1.3.8 Telemetry of physiological parameters

Special tags have been manufactured capable of transmitting information about physiological parameters such as the rate of heart beat of a fish. These tags are usually used under aquarium conditions or in relatively enclosed bodies of water. This is important; otherwise the fish may stray too far from the equipment needed for monitoring these signals.

1.3.9 Investigation of behaviour

This is a special case of 1.3.1, i.e., much about the behaviour of an animal can be inferred from a study of its movements. For this purpose, individuals may be marked in groups, or alternatively the movements of a single individual can be investigated by furnishing it with a sonic tag and recording the movements of the tag.

2. CAPTURE, HANDLING AND HOLDING

An important part of any marking experiment is the way in which fish are caught and handled. Some fish are relatively hardy and can withstand rough treatment. Other species are quite delicate and unless precautions are taken, may be severely damaged or killed.

2.1 Methods of capture

Fish for marking may be caught by any of the conventional fish capture methods although some are more suitable because they yield fish in better condition.

2.1.1 Active gears

These comprise fishing methods in which the fish are herded or encircled by the movement of pieces of netting.

The principal methods include seining (i.e., with Danish seines or similar bottom gear), trawling and purse seining.

Seines and trawls. Seining and trawling, although very good for catching large numbers of fish, are not always the most suitable for tagging since they do not necessarily yield fish in good condition. Problems are:

(1) The fish are herded, frequently to the point of exhaustion, before they pass down the net to the codend.

(2) Within the codend they may be subject to turbulence that can easily lead to further exhaustion.

(3) When the gear is hauled to the surface physoclistous fish may suffer internal damage due to expansion of the swimbladder. The greater the depth the greater will be the likelihood of this happening.

(4) When the codend is lifted from the water the fish within the codend may be crushed under their own weight. The larger the catch, the greater is the danger of this happening.

(5) Spiny fish (e.g., redfish) often puncture soft-fleshed fish (e.g., gadids) in the net. Similarly rough-skinned fish (e.g., sharks and rays) can scrape slime and scales off other fish.

It is not possible to compensate for all these disadvantages. By taking some precautions, however, it is usually possible to obtain a certain proportion of the catch from a trawl or seine in good enough condition for marking. For example, by reducing the duration of a haul, it is possible to reduce the period during which fish may be unduly stressed or exercised within the net. Fishing where coarse or spiny fish are scarce will minimize damage by punctures and scraping. By fitting a canvas bag within the codend as described by Jones (1971), the fish can be supported within a container of water as they are lifted out of the sea. Fig. 1 shows how the codend can be positioned to release fish and water directly into a deck tank.

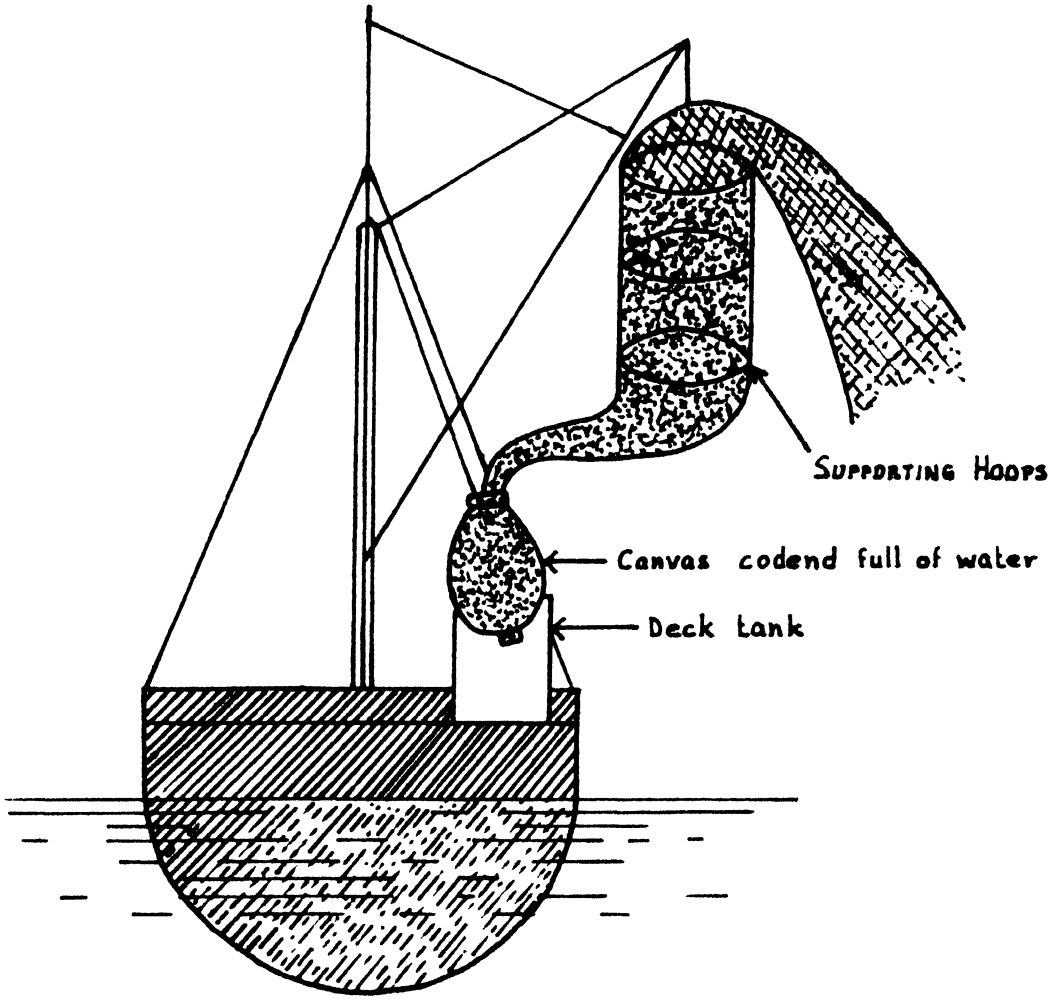


Fig. 1 - Canvas codend full of water in position over deck tank. Water and fish are released into tank by untying bottom of canvas bag (Redraun from Jones, 1971)

It ought to be possible to construct a special codend within which there is a region where fish can lie free from strong eddies and currents. If the codend is detached from the trawl at the end of the tow it can be brought to the surface slowly so as to reduce the effect of swimbladder damage in physoclistous fish. This was attempted by Jones (1971) but the results were not entirely satisfactory. It was concluded that until the hydrodynamics of water flow in the net and the codend are better understood, attempting to modify the flow through the net may cause the fish to become more fatigued than simply using a conventional codend. For example, supporting hoops, such as those shown in Fig. 1, were found to be unnecessary.

Raising the fish to the surface slowly is effective in reducing damage due to decompression, but it takes time. In some instances it may be better to mark a large number of fish quickly, knowing that many will die, than to try to get fish in very good condition at the expense of finishing up with relatively small numbers.

Purse seine. The purse seine is typically used for shoaling fish, the catching operation being in two parts.

(1) The shoal is encircled (Fig. 2a) and the bottom of the bag is closed by pulling on a pursing line threaded through rings at the base of the net (Fig. 2b).

(2) The net is then gradually hauled in until the catch is concentrated in a small bunt of netting close to the vessel. For tagging purposes the fish may then be brought on deck with a scoop net (Fig. 3) or the operator may arrange matters so that the fish can be tagged while still in the water (Fig. 4).

2.1.2 Passive gears

Principal gears in this category are gill nets, trammels, traps, and hooks and lines. In all these methods the gear is stationary or practically so, and the fish are captured when they come into contact with the gear.

Gill nets and trammels typically mesh the fish. There is then a danger of loss of condition due to struggling and exhaustion, depending on the length of time that elapses before the net is hauled in (Fig. 5). Gill nets can also cause extensive scale loss, and muscle damage due to constriction (Murray et al., 1969).

When lines are used there is also a danger of exhaustion. This is more likely to be the case if longlines are used, and fish condition is usually better if the fish are caught on handlines and thus brought to the surface as soon as they are hooked.

Rupture of the swimbladder of fish caught in fairly deep water can be avoided if they are brought to the surface slowly. Figs. 6a and 6b show how a cage with a one-way gate at a the bottom can be fitted onto a handline and dropped from a boat over a hooked fish. Figs. 6c and 6d show in detail the mechanical system for breaking the leader off the fishing line once the fish is in the cage. The leader is attached to a loop of low breaking strength that holds the two rings together, so when the smaller ring passes through the small opening at the top of the cage as the line is hauled, the full weight of the cage rests on the weak loop, which breaks, leaving the fish to swim freely in the cage. The cage can then be brought slowly to the surface.

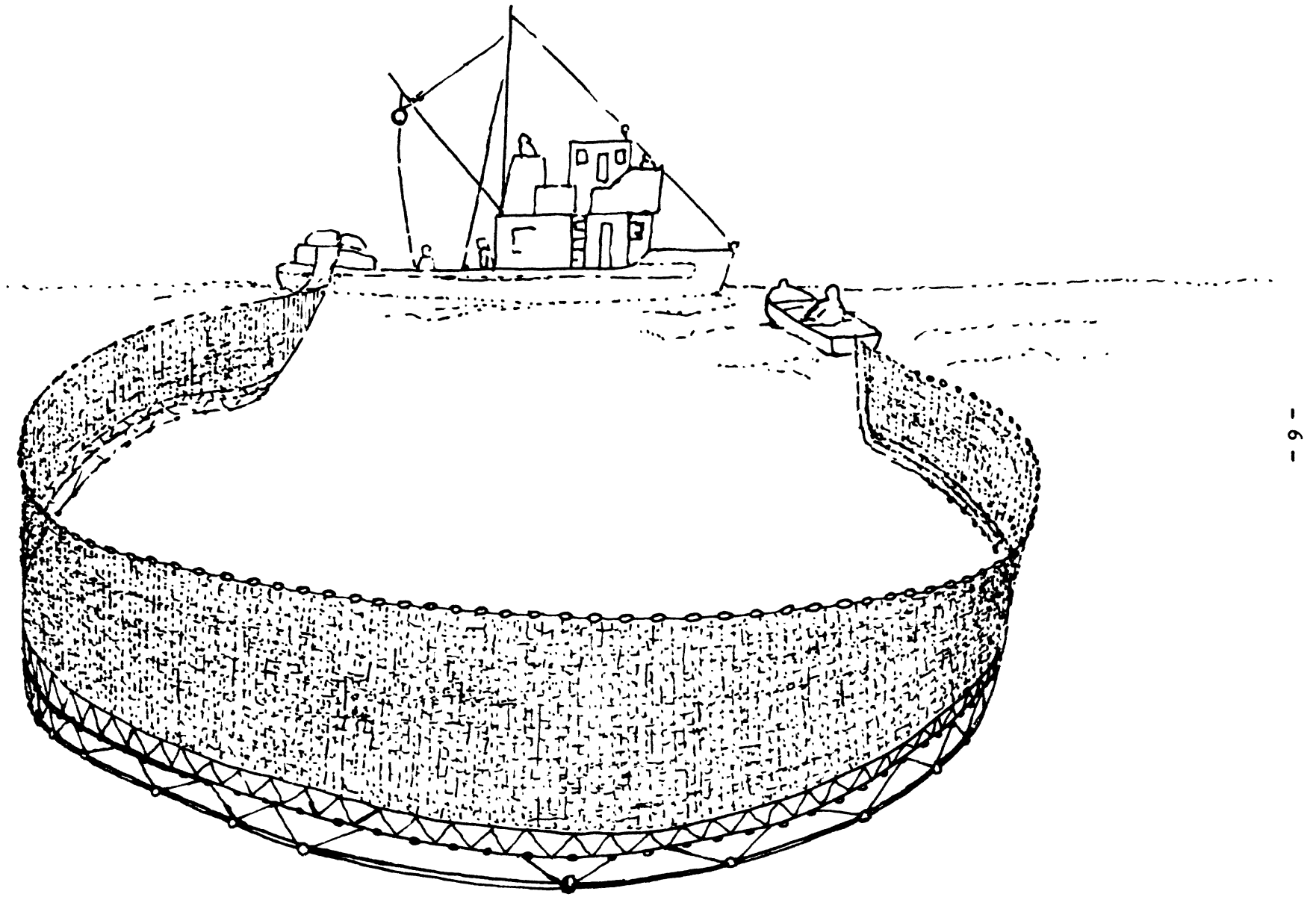


Fig. 2a - Purse seine: Shoal being encircled
(Redrawn from Lagler, 1968)

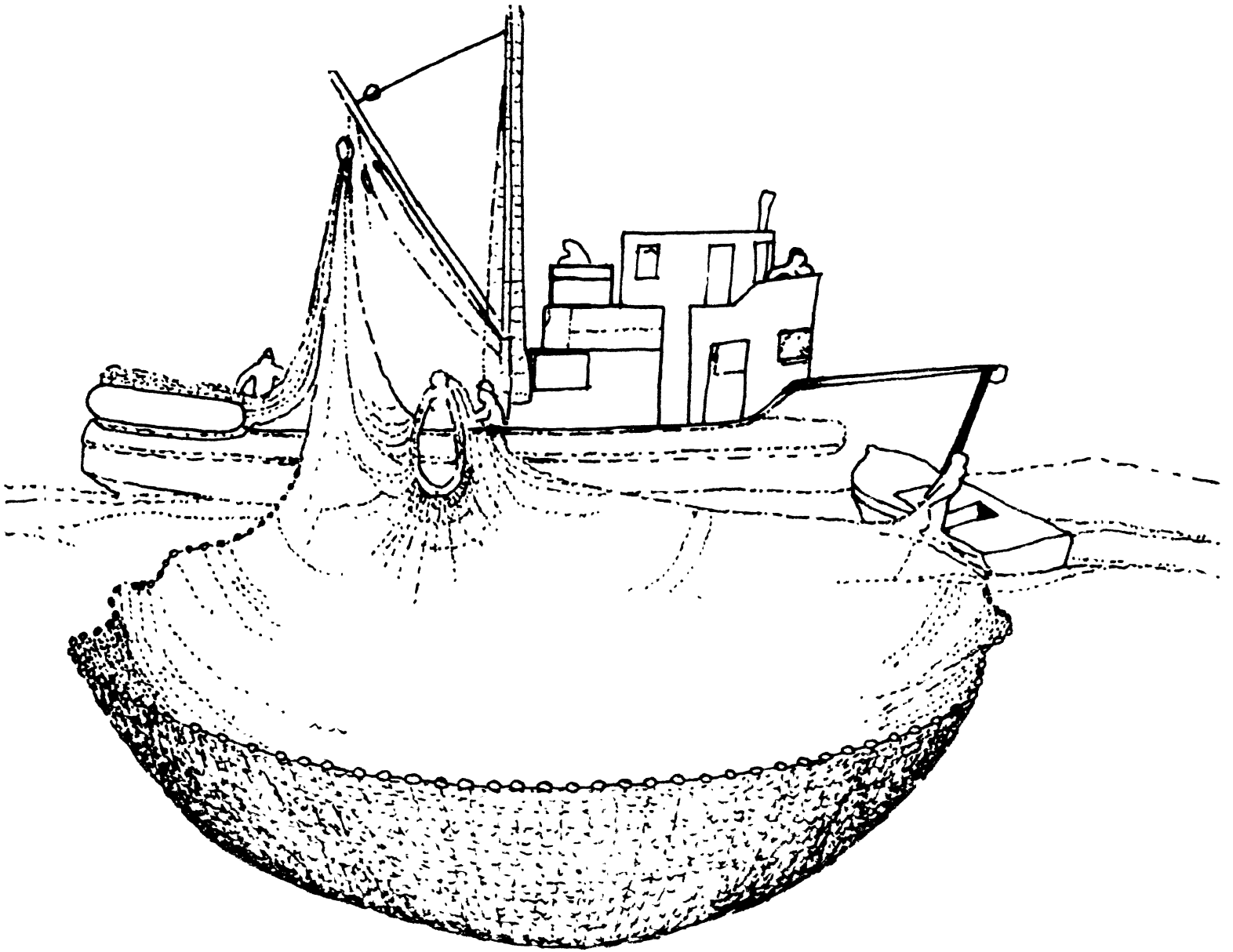


Fig 2b - ine et closed at bottom and being hauled ab
Redrawn from (Ogler, 1968)

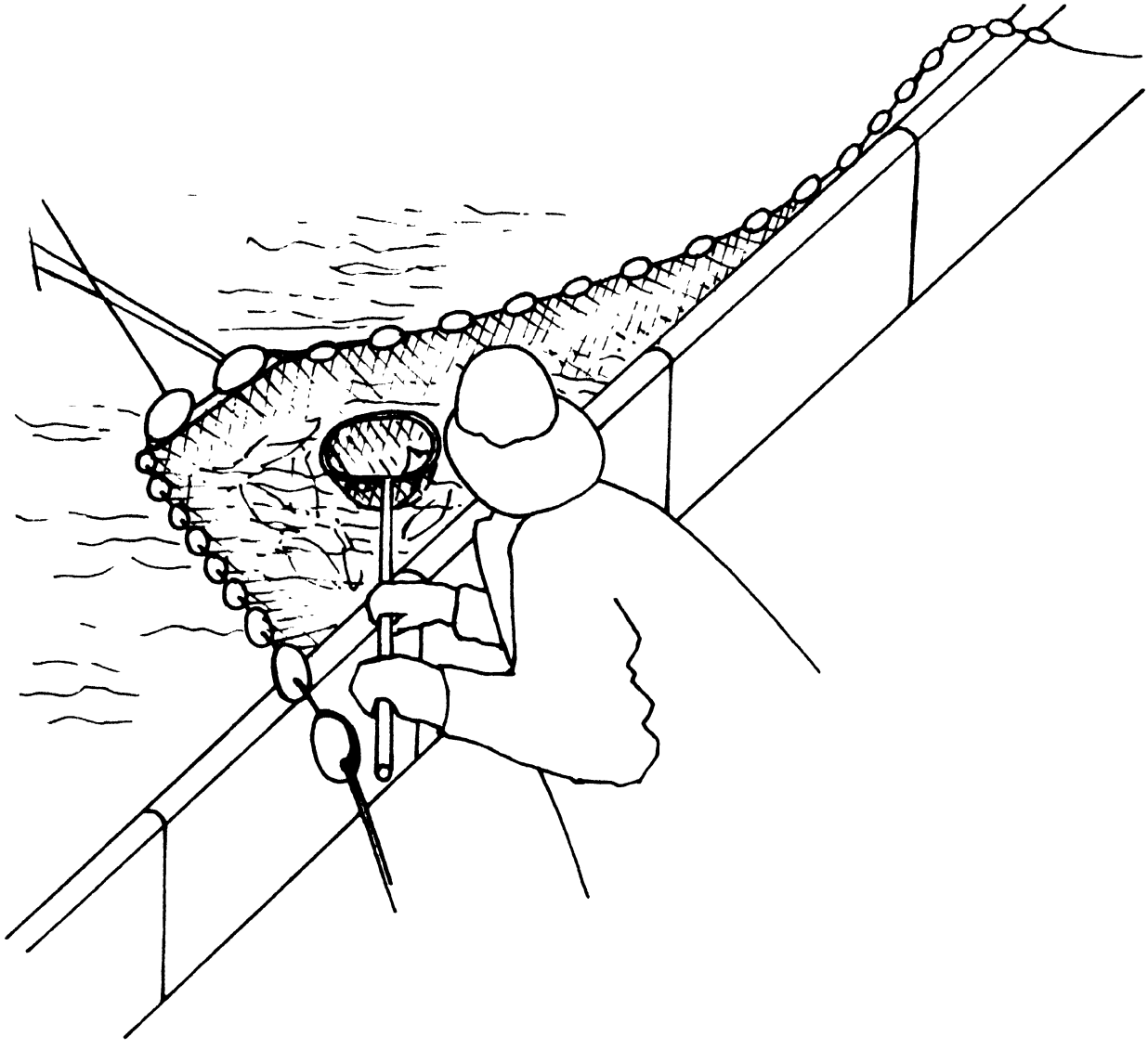


Fig. 3 - Fish being removed from the bunt of a purse seine using a scoop net (Redrawn from Hartt, 1963)

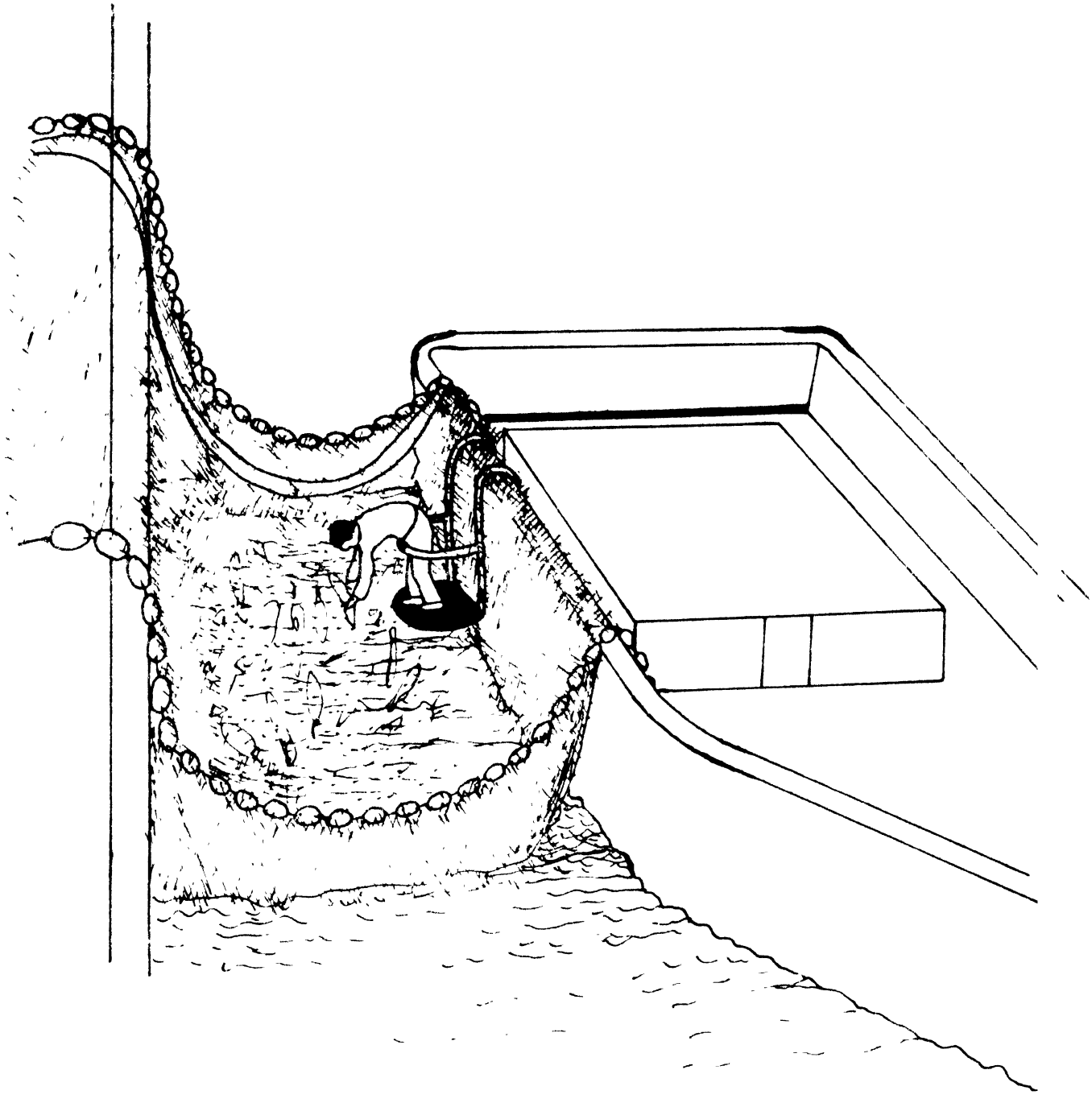


Fig. 4 - Man suspended in cradle from small boat, tagging fish in the bunt of a purse seine (Redrawn from Bayliff, 1973)

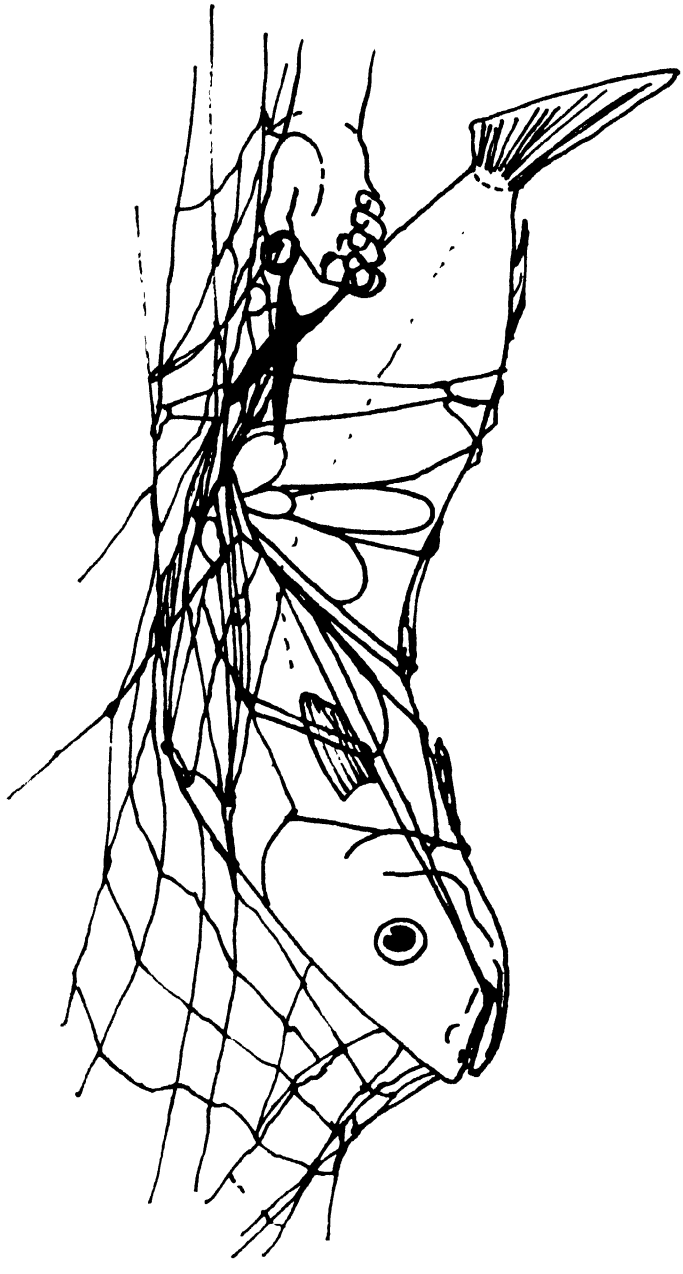
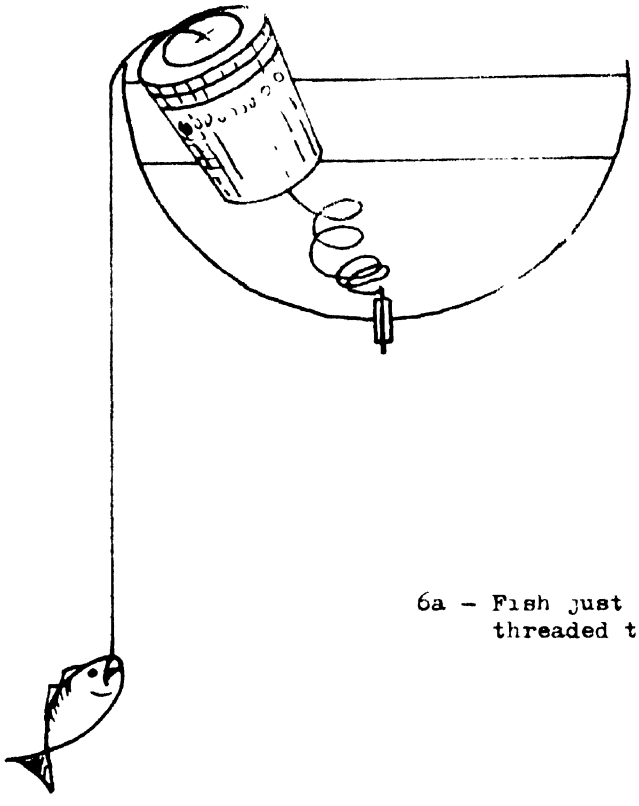
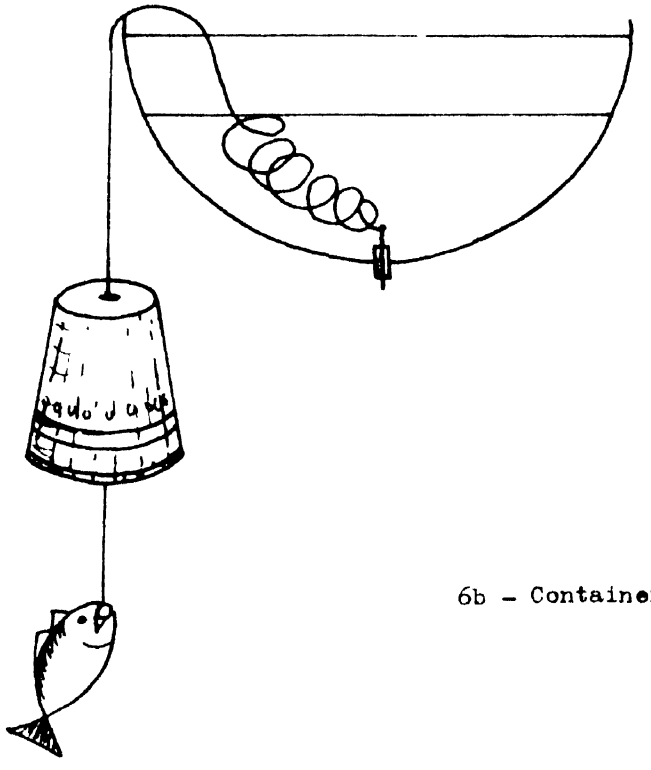


Fig. 5 - Cutting the meshes to free a fish that is tangled in the net (Modified from Lagler, 1968)

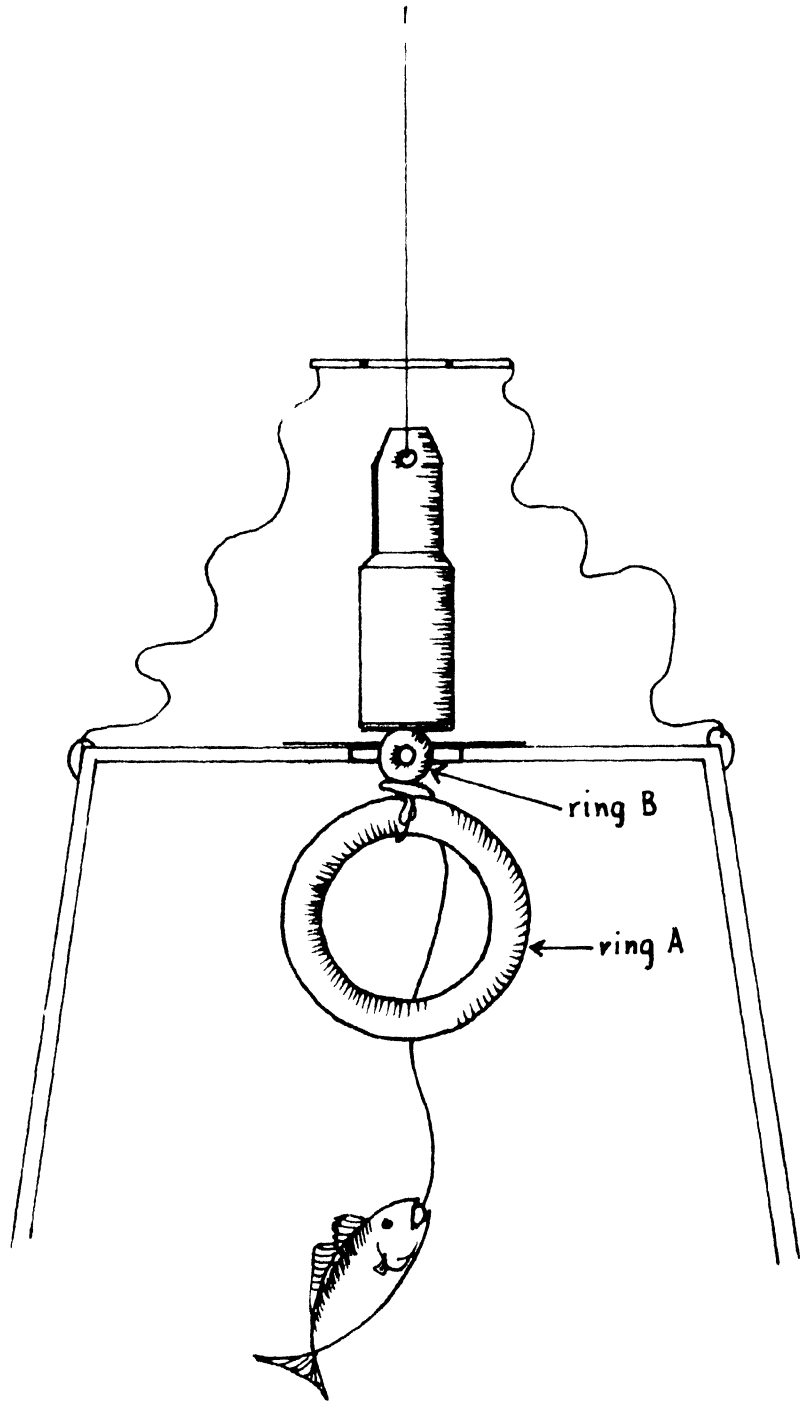
Fig. 6 – Sequence for introducing a hand line-caught fish into a container



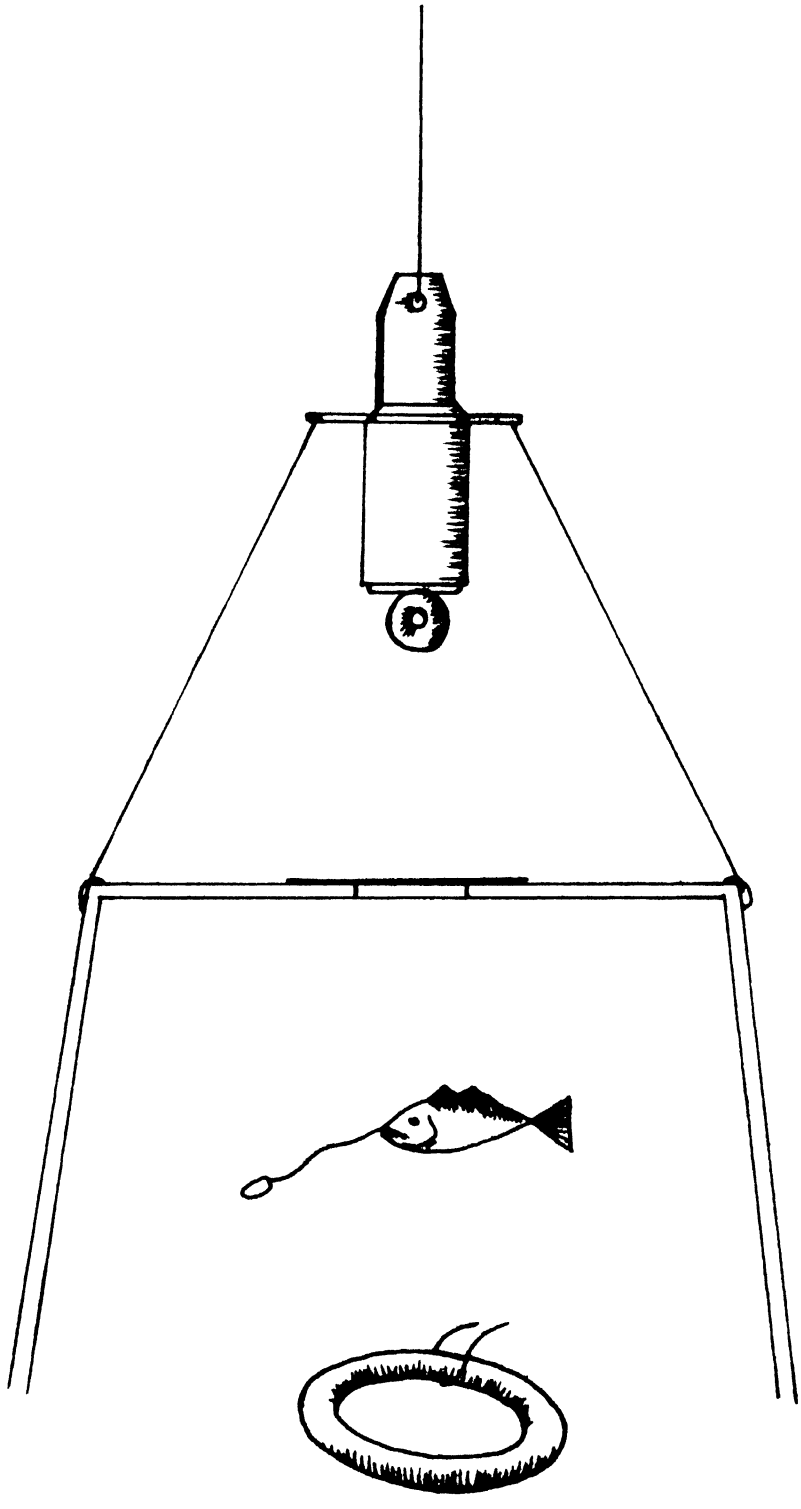
6a – Fish just caught on handline in normal manner – line threaded through container which is still in the boat



6b – Container dropped over side and sliding down line



Fish inside container - full weight of container about to come onto Ring A. This is too large to pass through hole in top of container. Ring A is attached to Ring B by a single thickness of thin nylon and a sharp tug on the line causes this to break



6d – Situation immediately after Ring A has broken away from Ring B. Fish still carries hook and short length of gut, but is free from main line (Redrawn from Jones, 1971)

A special case of hook and line fishing is live bait (pole and line) fishing for skipjack and other surface swimming tuna. In this technique the fish can be brought on deck almost immediately they strike the hook, and by reducing the handling time on deck to a minimum live-bait fishing has been successfully used to tag delicate species like tuna.

Where it is possible to use traps with or without the use of bait this is likely to provide the best way of obtaining fish in good condition. The trap may be constructed so that fish can enter easily but find it difficult to get out again (Fig. 7). A trap may be fitted with an automatic device that closes the entry after a predetermined time period. Alternatively, it may be operated in conjunction with underwater television, and provided with a means of closing the entry when it is seen to contain sufficient fish. The size and colour of the trap may influence the activity of captured fish and hence their condition.

2.1.3 Electrofishing

This involves creating an electrical field in the water by passing a current between two submerged electrodes. It may be operated using either alternating current or direct current. If an alternating current is used, the fish can be stunned and removed from the water using a dip net. If a direct current is used the fish can be made to move toward the anode and removed with a dip net. This method has been used with considerable success in fresh water.

2.1.4 Removal of water

In inland waters it is sometimes possible to isolate a particular area and remove the water until the fish are concentrated in one corner. In some parts of the world where there is heavy rainfall fish may be concentrated naturally as floodwaters subside.

2.1.5 Use of local knowledge

Wherever possible, consultation with local fishermen, so as to make the best use of local knowledge, is likely to be advantageous. Kelly and Barker (1963a and b) describe how redfish, which is normally a deep water species, comes to the surface to feed during the ebb tide at night in Eastport, Maine, and can readily be caught on hook and line. Costello (1959) pointed out the advantage of hiring an experienced commercial fisherman for catching suitable quantities of shrimps in good condition.

2.2 Handling and holding

Care in handling and holding, particularly when dealing with delicate fish, can be an important factor in determining the success or failure of a marking experiment.

2.2.1 Removing the fish from nets or hooks

It is most important that fish for marking should be removed from the catching gear with the maximum amount of care. During normal trawl or seine fishing operations, for example, the fish are lifted from the water in a bag of netting and dropped on to the deck. This can cause physical damage. Also it can expose the fish to sunlight and on bright, sunny days, this may cause retina damage. Jones (1971) describes how these effects may be minimized by fitting a canvas bag inside the codend so that the fish can be dropped directly into a tank of water on deck (Fig. 1). When fish are removed from gill or trammel nets they should be disentangled carefully and if necessary the meshes in which they are entangled should be cut (Fig. 5). Line-caught fish should not be allowed to dangle on the line out of the water for any longer than is necessary. When dealing with very large fish it may be better to tag the fish in the water without attempting to lift them out (Fig. 4).

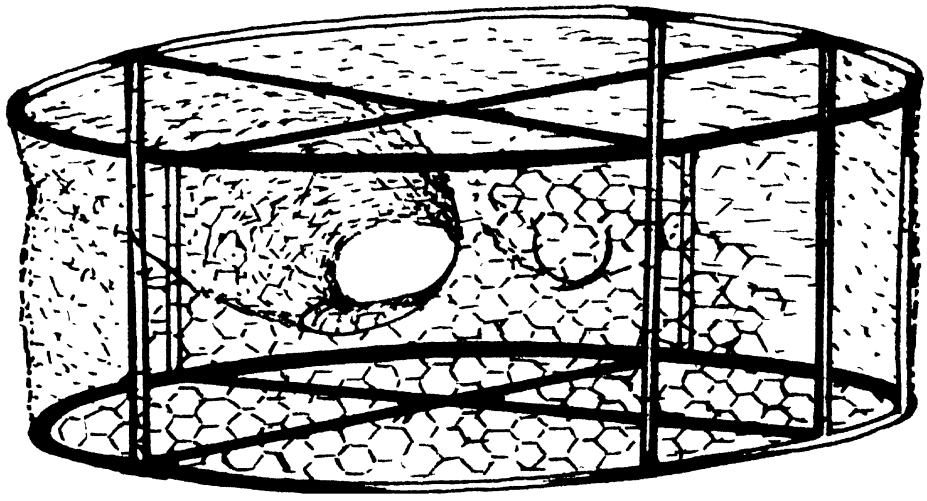


Fig. 7 - Trap with funnel-shaped entrance devised to make entry easy but escape difficult (Redrawn from Collyer and Young, 1953)

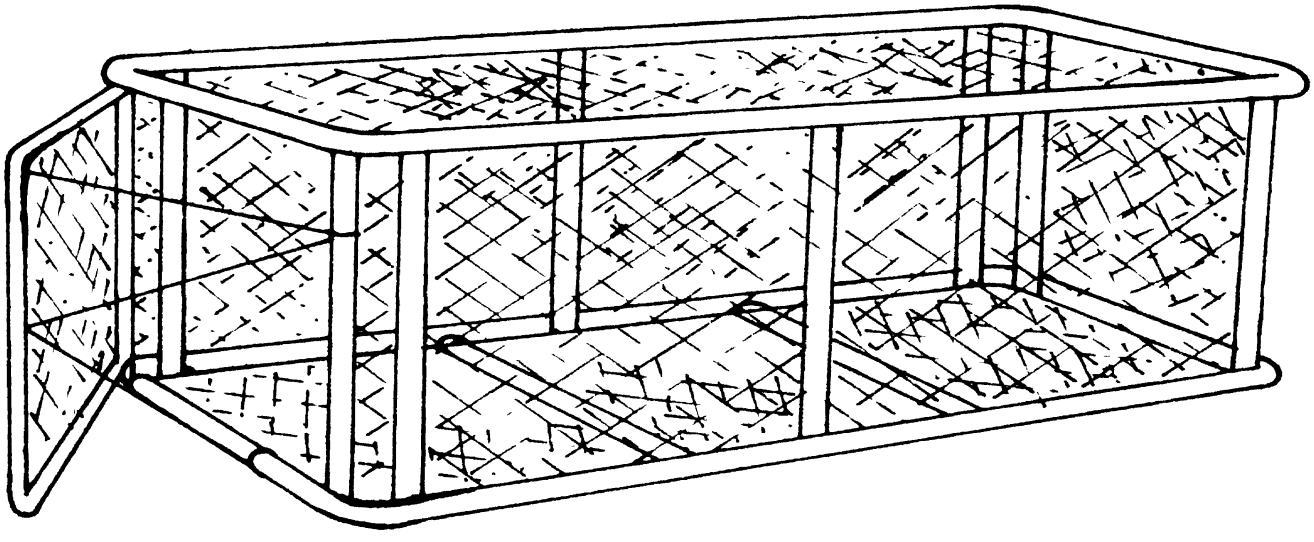


Fig. 8 - Live cage (Redrawn from Akyüz, 1965)

2.2.2 Containers in the water

Various workers have described containers that may be kept submerged in the water for holding fish both prior and subsequent to tagging. For example, Janssen and Aplin (1945) describe a live box for holding sardines. This is similar to the live boxes used by live bait fishermen in southern California. It consists of a wooden float with 4 empty 50-gall oil drums to give it buoyancy. The fish compartments are wooden frames 6 ft square and 4 ft deep covered with netting. The tops are covered with wire screens to keep out predators and excessive sunlight. Because of marine growth it is necessary to clean the sides every week to allow continued circulation of water.

Fish can be carried to the floating live box in a boat and transferred by dip net. For subsequent removal each compartment can be furnished with a curtain of webbing that can be manoeuvred for concentrating the fish into a corner of the compartment. As fish are tagged they can be placed in an adjoining compartment and released in groups.

Another device, consisting simply of a small boat with holes in it, is described by Kurata (1954).

Two styles of live fish containers are shown in Figs. 8 and 9.

2.2.3 Deck tanks

Deck tanks may be fairly permanent installations furnished with running water, or portable devices. For example, Stott (1968) shows the use of a modified rubber dinghy for a holding tank (Fig. 10). Portable tanks such as that described by Fridriksson et al. (1960), can be made by using a strong waterproof canvas supported on a metal frame (Fig. 11). More permanent deck tanks are illustrated by Hartt (1963) (Fig. 12).

2.2.4 Transfer of fish

For transfer of fish a dip net can be used. This may be relatively shallow or somewhat deeper as shown in Fig. 3. Different species tend to struggle to a different extent in nets of differing designs. It is recommended that the design of net be chosen experimentally so as to minimize the tendency of the fish to struggle.

2.2.5 Tagging troughs and holders

There are various ways of holding fish for the actual tagging operation.

If the fish are prepared to lie quietly it may be sufficient to lay them on a flat board. If the fish are to be measured a measuring board is most convenient for this purpose (Jensen, 1958) (Fig. 13).

A simple method for tagging only is to hold the fish firmly in the cup of one hand and to insert the tag with the other hand. For tagging kelp bass, Collyer and Young (1953) used a cotton glove with a soft leather palm on the left hand to hold the fish during the tagging operation. Small fish can be held in a pan of water and tagged underwater.

Parrish and McPherson (1963) experimented with a device for holding a herring in a stream of water while being tagged (Fig. 14). An alternative device is shown in Fig. 15. Kotthaus (1963), working with soles, used a holder constructed of two boards 40 x 25 cm, each covered with thick plates of foam rubber and folded together (Fig. 16). For the tagging operation a fish is taken out of the holding tank and gently squeezed between the two boards of the holder. The foam rubber in the holder is saturated with water to keep the fish wet. The tag is attached and the fish is measured and released immediately.

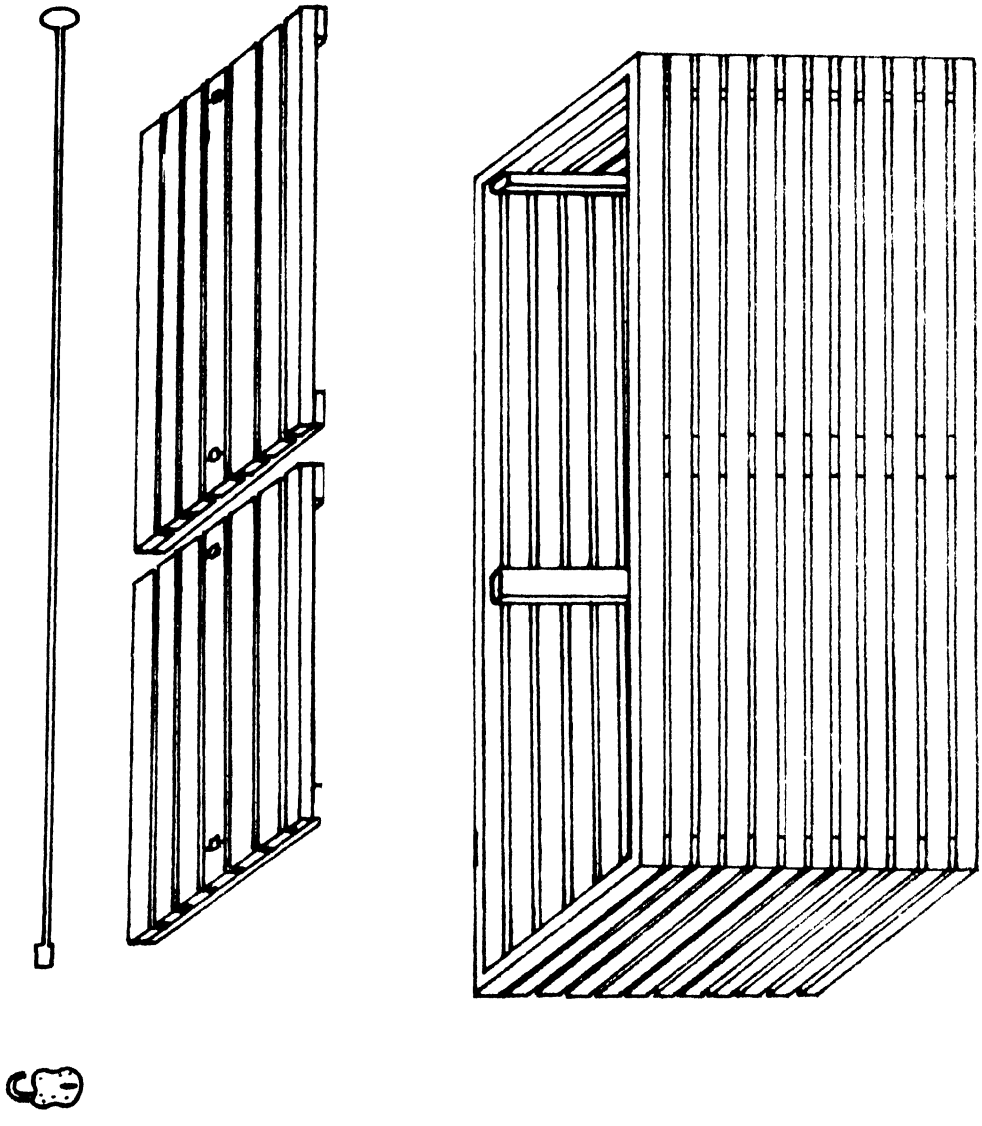


Fig. 9 - Live cage (Modified from drawing in Stott, 1968)

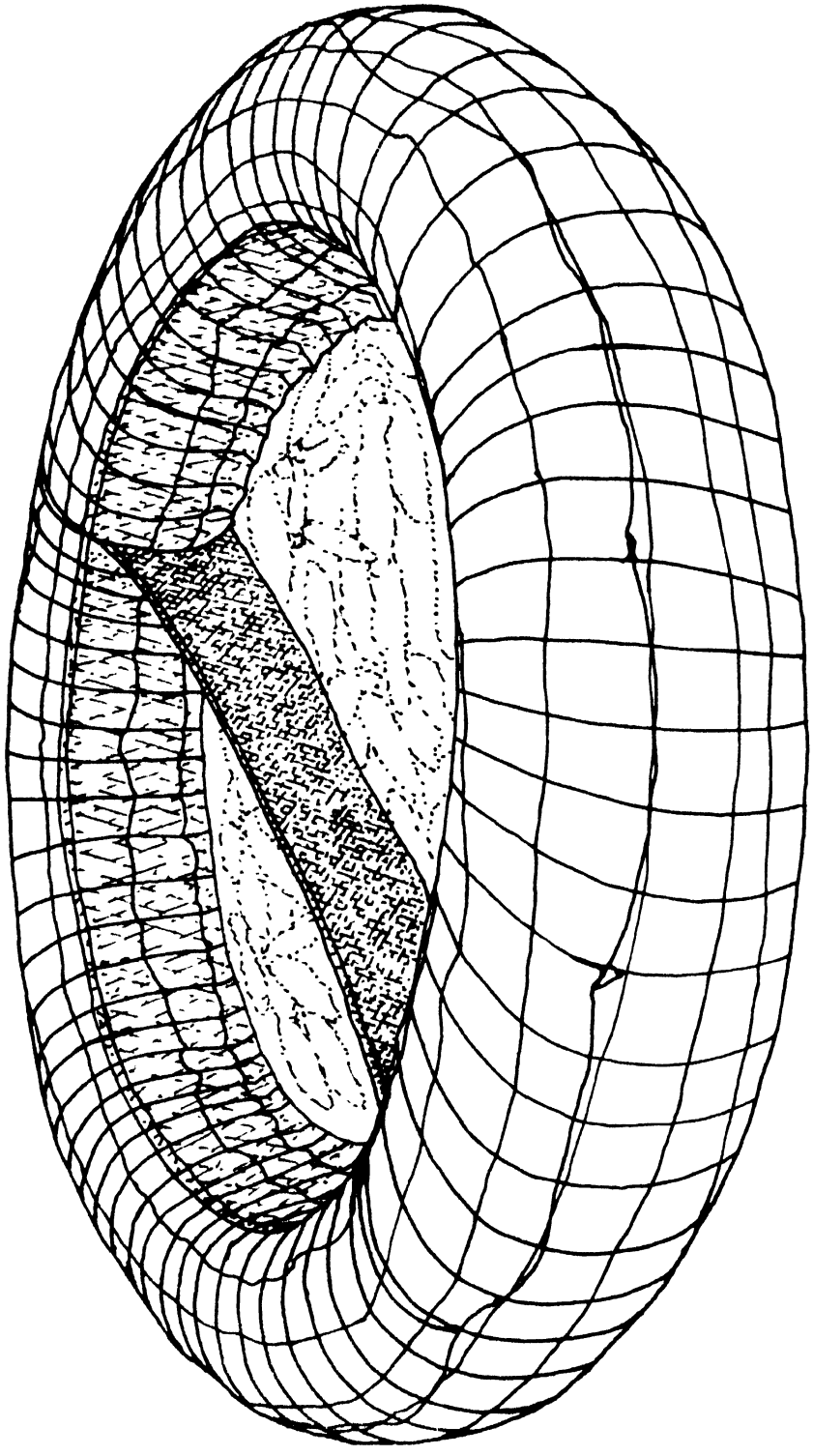


Fig. 10 - Rubber dinghy modified for use as a deck tank
(Redrawn from Stott, 1968)

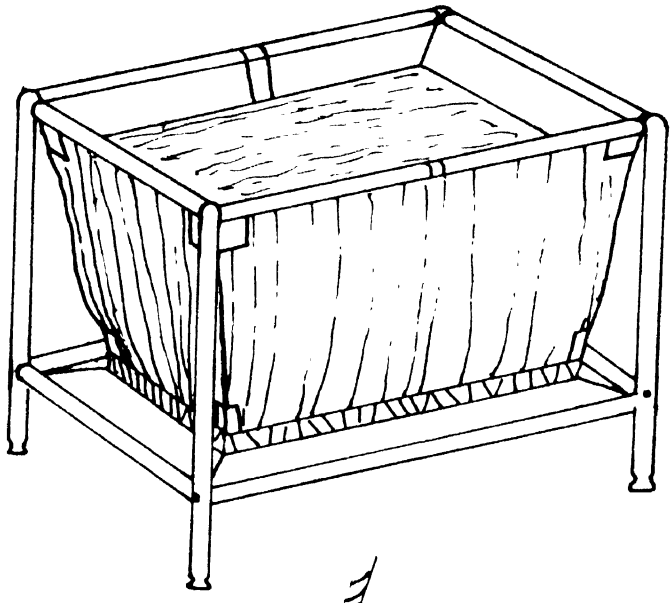


Fig. 11 - Portable tank consisting of a metal frame and a canvas tank (Redrawn from Fridriksson et al., 1960)

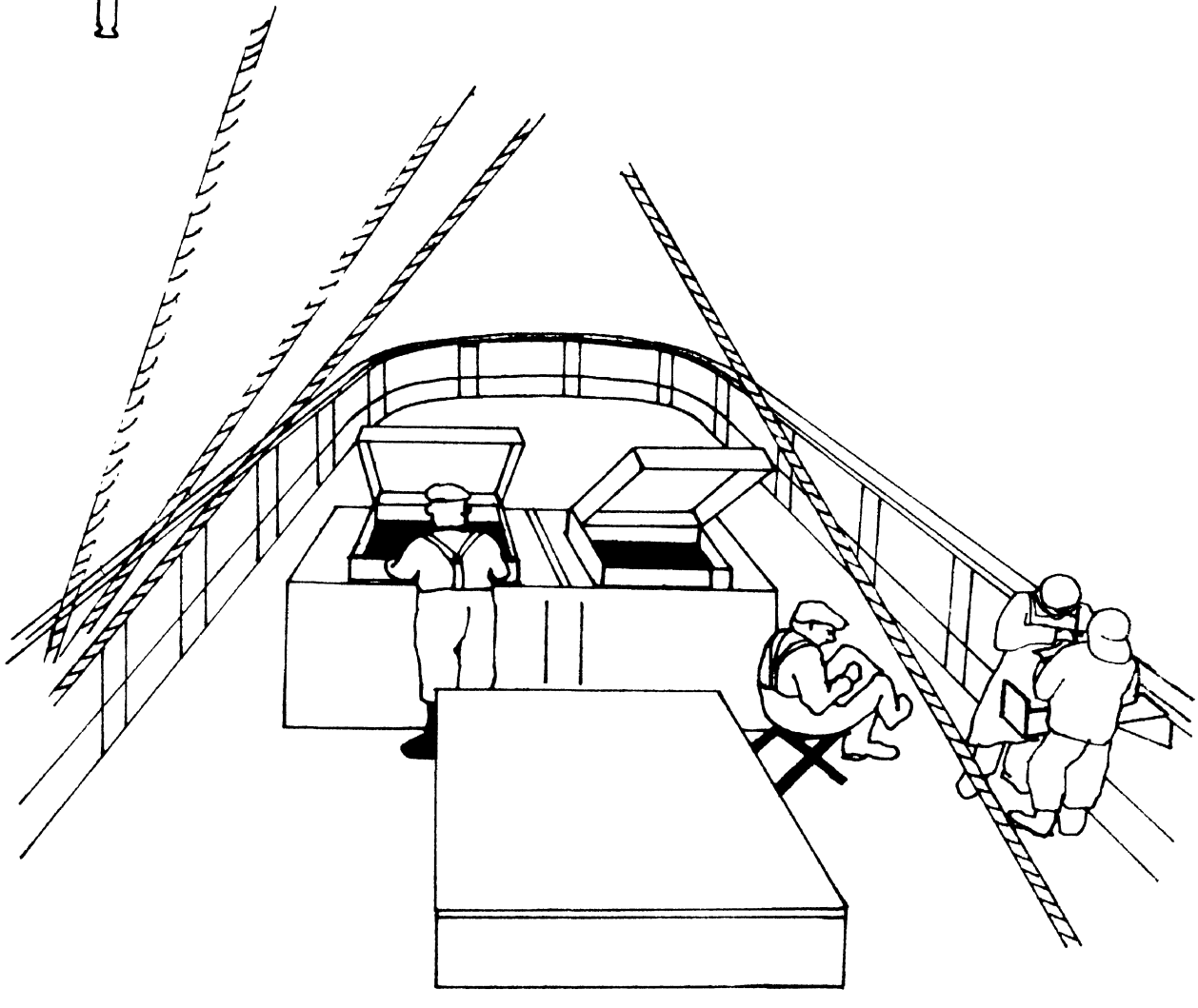


Fig. 12 - Fitted deck tanks (Redrawn from Hartt, 1963)

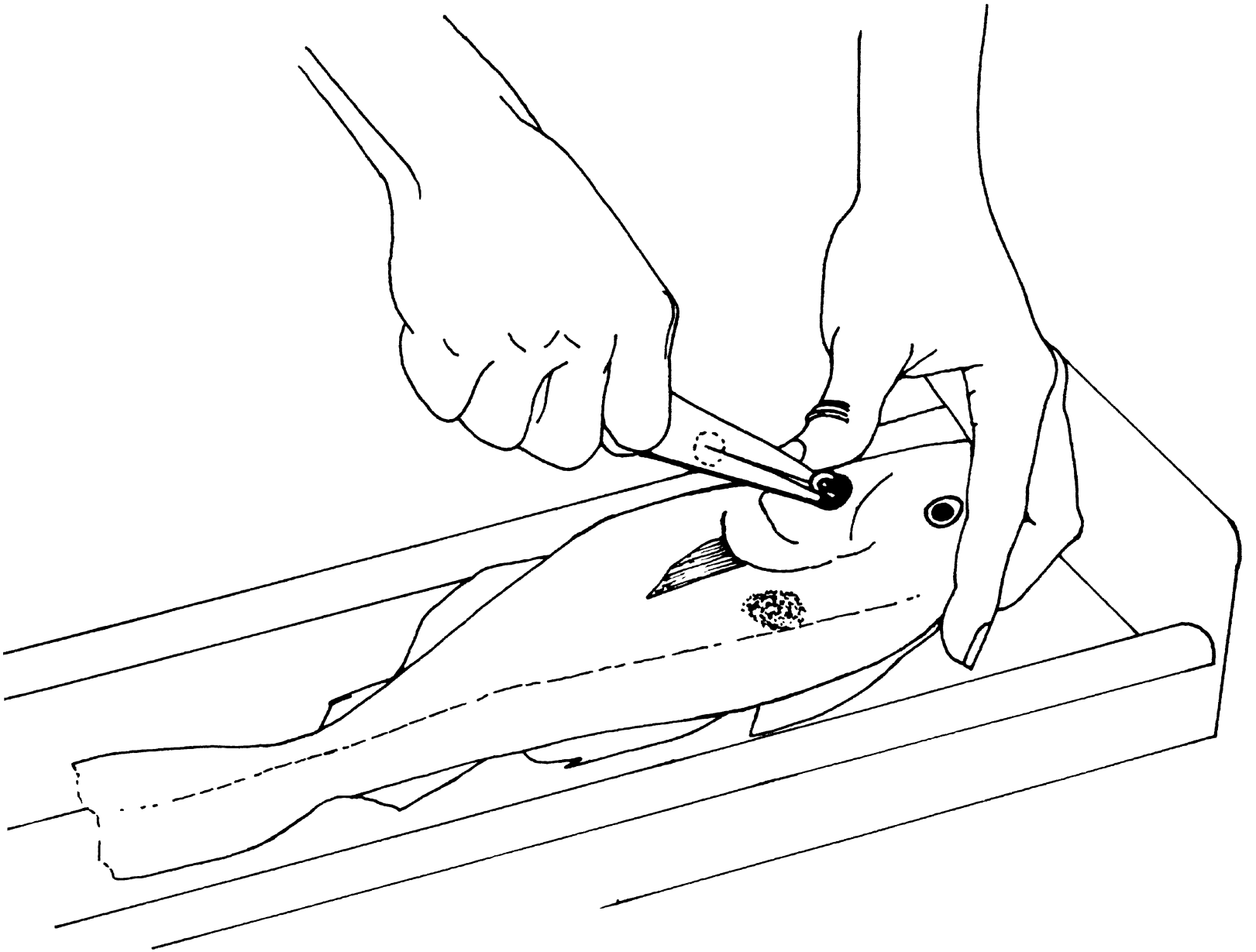


Fig. 13 - Haddock laid flat on board - ready for measuring and tagging. The operator is just finishing the attachment of a Petersen tag to the operculum (Redrawn from Jensen, 1958)

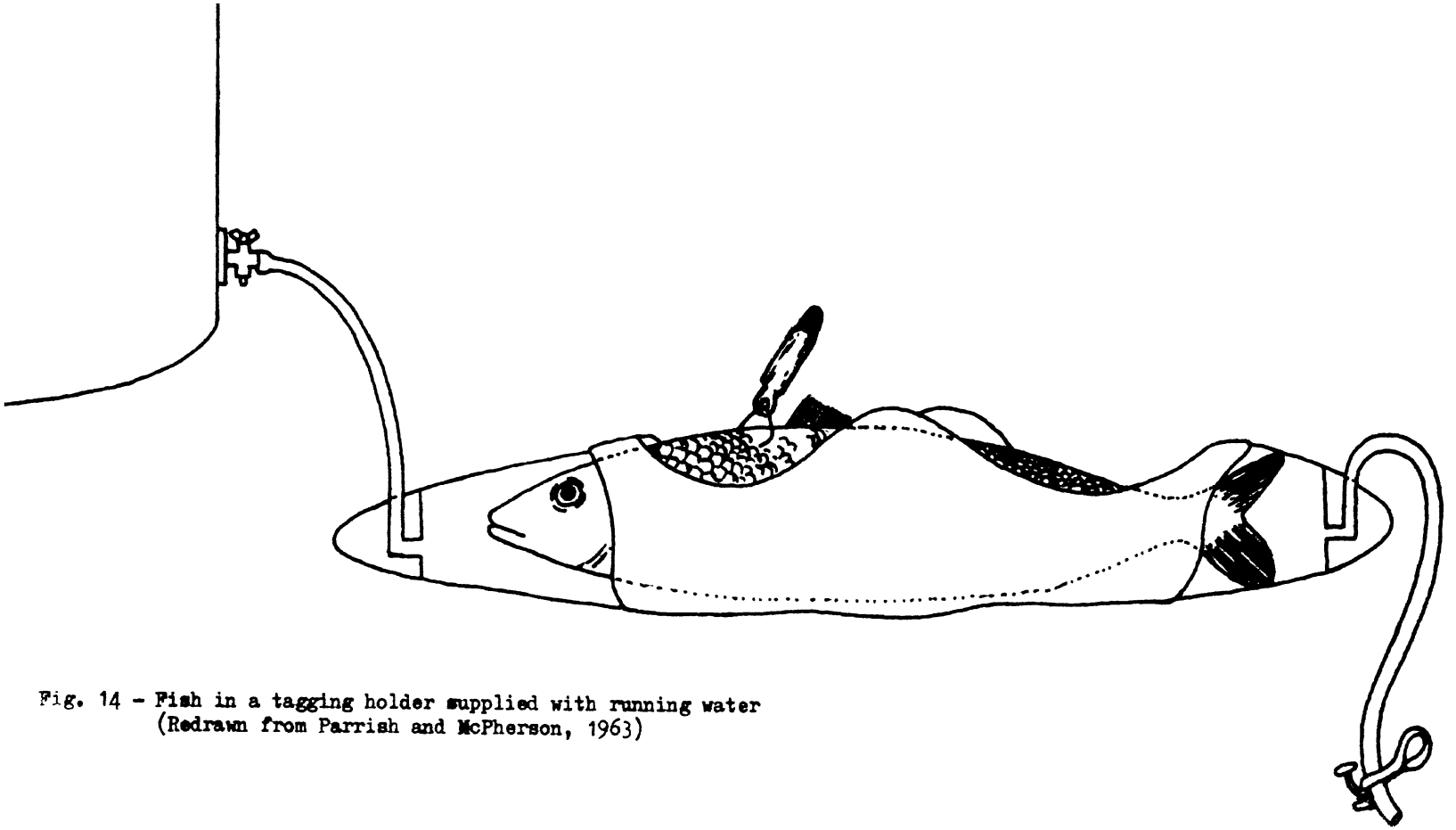


Fig. 14 - Fish in a tagging holder supplied with running water (Redrawn from Parrish and McPherson, 1963)

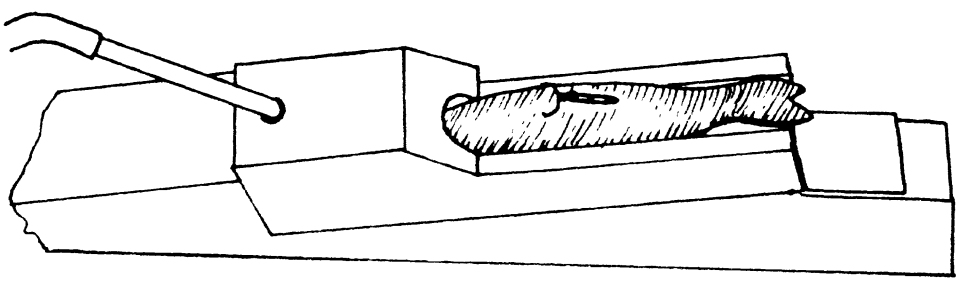


Fig. 15 - Fish in tagging holder supplied with running water (Redrawn from Smith, 1957)

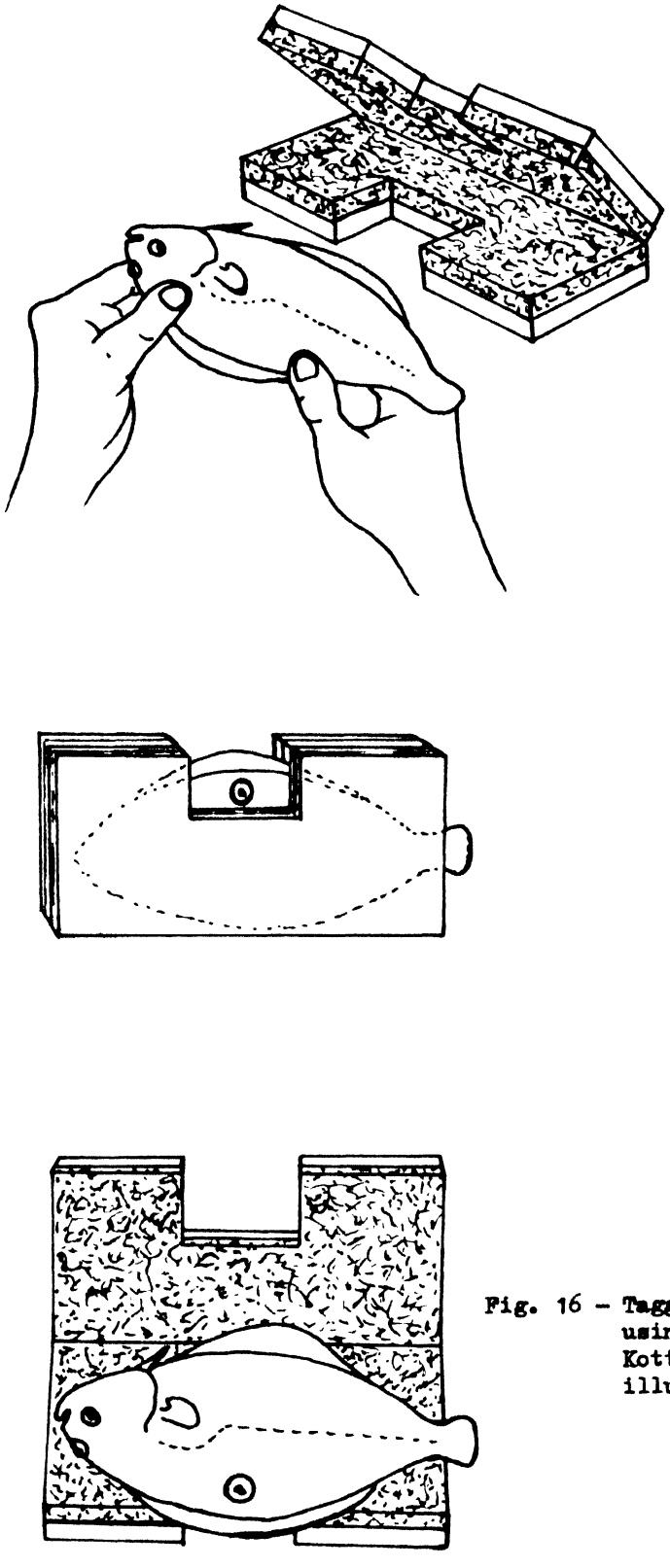


Fig. 16 - Tagging sequence for a flatfish using sole holder designed by Kotthaus, 1963 (Modified from illustrations in Kotthaus, 1963)

Aslanova (1963) used different sizes of tagging cradles ranging from 30 x 1 x 9 cm t 80 x 30 x 20 cm depending on the species and size of fish. Hartt and Pitcher (1969) placed anaesthetized fish on foam rubber pads which were kept wet.

Fink (1965) describes a tagging cradle used for tunas. The cradle is about 8.6 kg and strongly constructed. The framework is of aluminium alloy 3.18 mm thick. "The V-shape notch and snoutguard are covered by 25 mm of medium density polyurethane foam which is in turn covered by heavy duty vinyl plastic. The baffle separating the notch and the tag magazines is made of 19 mm hardwood. The snoutguard support is made of exterior grade Douglas fir plywood painted in marine enamel. Polyurethane foam and vinyl cover are cemented to each other and to the aluminium frame using either EC-104 cement or No. 77 spray adhesive. These are rubber based with a petroleum naptha solvent manufactured by the Minnesota Mining & Manufacturing Co of St. Paul, Minnesota". A somewhat modified version is shown in Fig. 17. Covering the foam pads with smooth vinyl reduces the loss of slime, which can be rubbed off by uncovered foam rubber or foam plastic.

Bayliff (1973), working with tuna, noted that covering the eyes of the fish with one hand during tagging reduces their struggles considerably.

An arrangement for transferring small fish from a holding tank, through an arrangement of sluice gates to a tagging cradle (Fig. 18) has also been described (Aasen, 1953; Fridriksson et al., 1960, and Akyüz, 1965).

2.2.6 Large fish

Mather (1963) found that blue-fin tuna weighing up to 60 lb, which had been caught by trolling, could be swung into a trough, marked and returned to the water in less than 45 sec. A tail strap was used to aid in lifting the larger individuals.

Hansen (1963), working with sharks, noted that when a shark is hauled to the surface on a line, an unbarbed hook on a long stick can be used to haul its tail out of the water so that a loop can be wound round it. The shark can be hoisted up by the tail along the side of the ship, measured and tagged, the hook removed and the fish released.

Mather (1963) also mentions that it is not necessary to handle the fish or even remove them from the water. Purse seine fish can be concentrated against the side of the vessel in the net and arrangements made for the tagger to be suspended over the side of the vessel so as to tag the fish while still in the water (Fig. 4).

Aslanova (1963) notes that very large fish over 75 cm in length can be measured without removing the fish from the pond.

2.2.7 Underwater tagging

Hislop (1969) described a method used for handling and transferring haddock underwater. The fish were caught by trawl or Danish seine. When the divers reached the codend they closed off its mouth by use of a throttling rope and detached it from the net by pulling on a nylon draw cord.

Tagging was carried out on the sea bed using four divers. Two divers tagged the fish with the aid of an underwater tagging bench (Fig. 19). The other two divers captured fish from the codend using polythene bags. Experience showed that fish could be caught underwater very easily by trapping them in the folds of the meshes, and the process of transferring them to plastic bags was relatively simple. Within the bags the fish did not struggle and an advantage of the method is that the fish are never handled directly by either the catchers or the taggers.

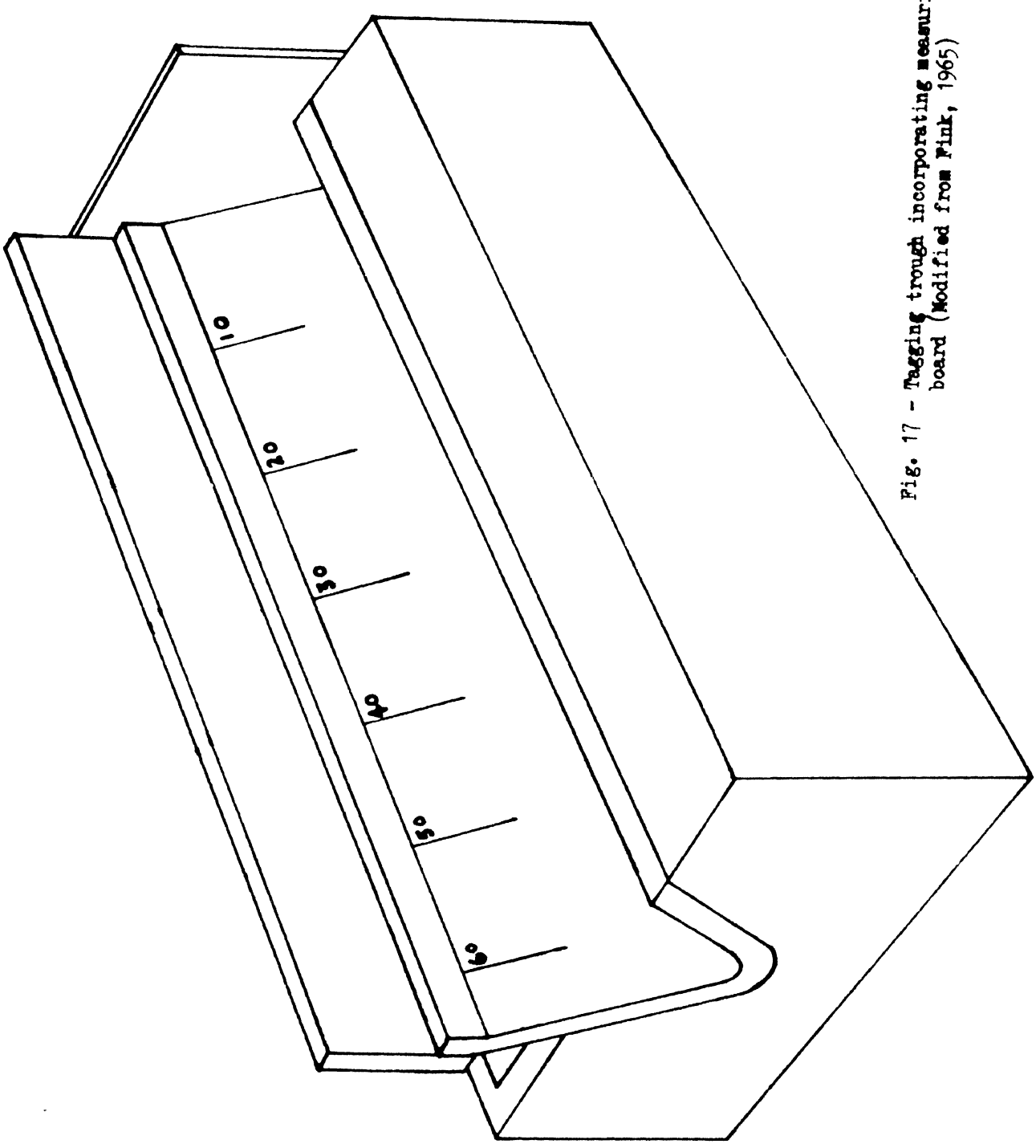


Fig. 17 - Tagging trough incorporating measuring board (Modified from Fink, 1965)

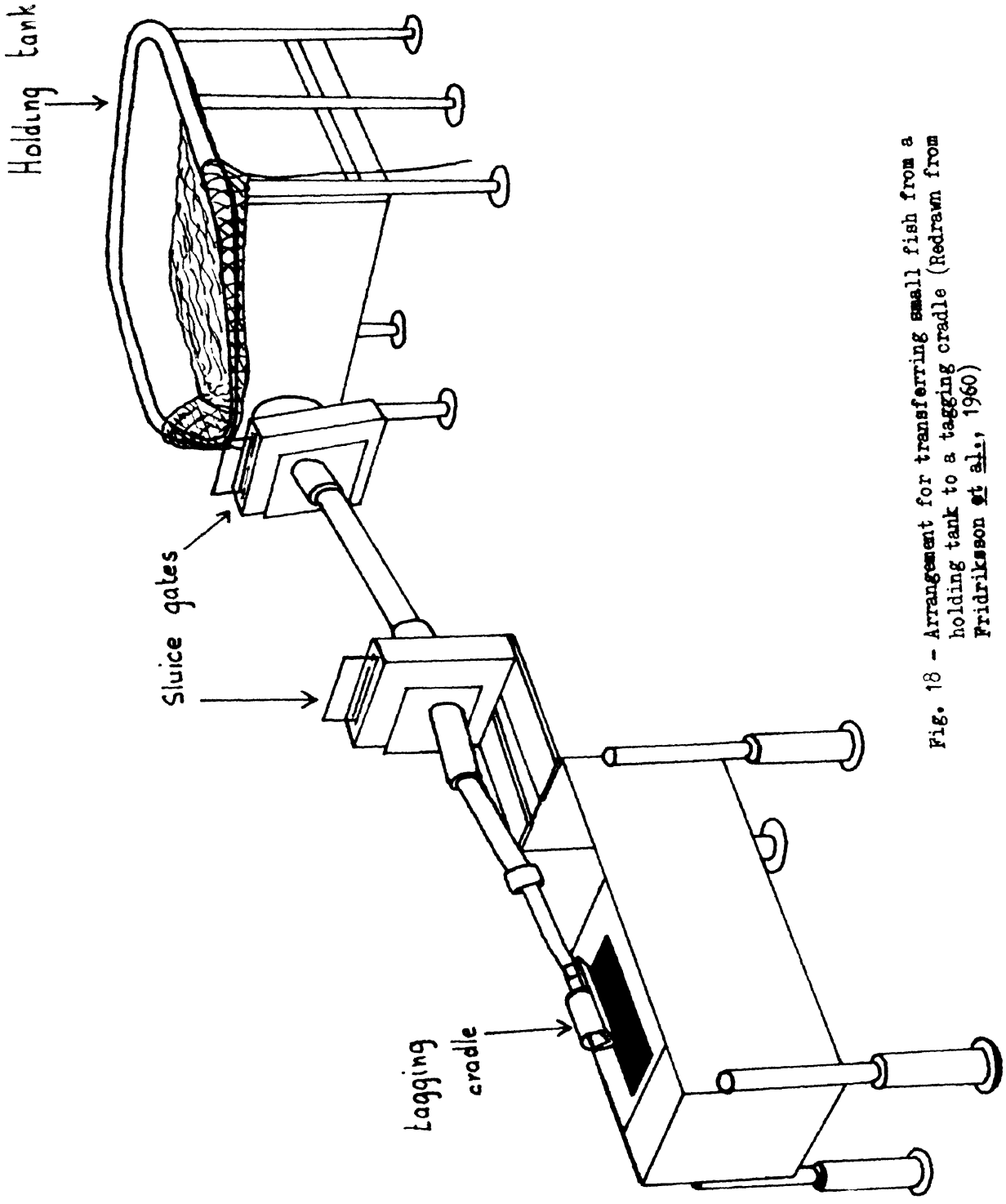


Fig. 18 - Arrangement for transferring small fish from a holding tank to a tagging cradle (Redrawn from Fridriksson et al., 1960)

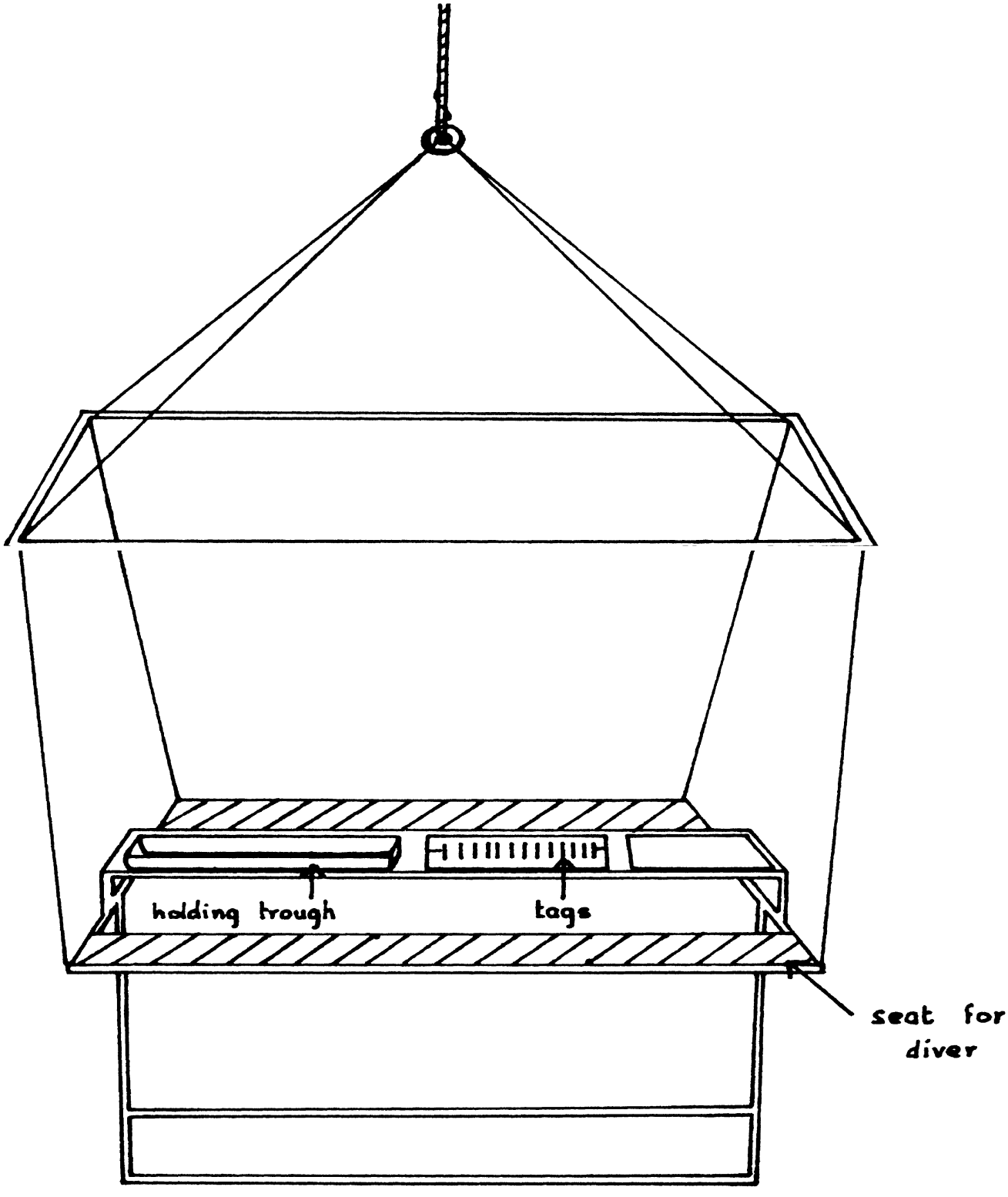


Fig. 19 - Underwater tagging bench
(Redrawn from Hislop, 1969)

2.2.8 Tagging speed

Many authors have stressed the importance of tagging rapidly. For this reason it is desirable to use as many workers as needed to make the whole operation as efficient as possible. The number of workers employed will depend on circumstances and objectives. For example, for some purposes staff may be limited and a one-person tagging operation may be desirable (Parrish and McPherson, 1955).

In some instances there is no such limit on the number of staff and several individuals may constitute a team. On large vessels, a team may consist of two or three fish handlers, one or more taggers and one or more recorders (Fig. 12). The recorder usually has the task of handing the tags or the fish to the tagger as well as recording the tag numbers and the species and length of the fish.

Where the number of staff is limited it may be appropriate for the tagger to have a tape recorder in a water-resistant container on his back for recording numbers and fish characteristics (Bayliff, 1973).

Tagging speeds vary very considerably with species and objectives (and with tag type, weather, etc.). Parrish and McPherson (1955) note that under favourable weather conditions an operator using a one-man toggle tag can tag between 400 and 600 herrings during a drift net haul of 3 to 4 hours' duration.

Clark and Janssen (1945) working with sardines note that the return rate of fish from each succeeding 100 fish tagged tends to decline and they attributed this to operator fatigue.

2.2.9 Use of antibiotics

Experience shows that wounds caused by the tagging operation normally heal satisfactorily without the need for special treatment. Antibiotics have been used by some workers, however. For example, Bayliff (1973) working with tuna used an antibiotic spray for spraying the tips of all needles and the barbs on dart tags before use.

2.3 Anaesthetics

A number of substances have been used for anaesthetizing aquatic animals:

MS222 (Tricaine methanesulfonate). This is a fine, white crystalline substance. It is relatively stable and readily soluble in water. It has been widely used at a wide range of concentrations. For trout of about 20 cm in length the concentrations used are mainly from 1:5 000 to 1:25 000 (Meister and Ritzi, 1958). For very small fish such as Fundulus much weaker concentrations of about 0.005-0.007 g/gal have been used (McFarland, 1960).

Chloretone (Chlorobutanol). This is a coarse, white, crystalline substance. It sublimates readily and has a smell of camphor. According to Meister and Ritzi (1958) practical field concentrations for fingerling and adult sized salmonids lie in the range 1:1 000 to 1:3 000.

Quinaldine (2-methylquinoline). According to Meunch (1958), suitable concentrations for green sunfish, white crappie, yellow bullhead, golden shiner and goldfish lie between 5 ppm and 20 ppm.

Tertiary amyl alcohol. Concentration 4-7 ml/gal for Fundulus (McFarland, 1960).

Methylparafynol (= Dormison). Concentration 2.0–4.5 ml/gal for Fundulus (McFarland, 1960).

Chloral hydrate. Concentration 8.5–11.5 g/gal for Fundulus (McFarland, 1960).

In general the best concentration appears to depend on species and temperature, and particularly on size of fish. When using an anaesthetic for the first time it is recommended that the effect of different concentrations be investigated experimentally.

Parker, Black and Larkin (1963) point out that low temperatures can be used to tranquilize fish.

3. MARKING

This section includes not only the actual marking operation, but also the kinds of marks used, the attachment positions for tags, and a comparison of the results of experiments using different kinds of tags.

3.1 Kinds of tag

Details of fish marks used by members of the International Council for the Exploration of the Sea, and some other countries, are given in ICES (1965). Notes on the principal tags are given below.

Albrechtsen (arrow) tag (Fig. 20). An elongated tag which, according to Williams (1963), is made from PVC (polyvinyl chloride) sheet of .25 mm thickness. It is arrow shaped at one end and has a hole near the other, for securing the arrow.

Alcathene tag (Figs. 21a, b). A pear shaped tag referred to by Bertelsen (1955). It carries a groove in which an iron tag, of about the size and shape normally used for internal tagging, can be embedded in wax.

Anchor tag (Figs. 22a, b). This typically consists of an "anchor" inserted into the body cavity attached by a short length of chain to an external tag.

Archer tag (Fig. 23). This consists of one or two plates, attached by two wires one at either end.

Atkins tag (Fig. 24). A simple tag consisting of a bead or a flat plate attached to the fish by a thread or piece of wire.

Bachelor button (Fig. 25). Two plates or discs held together by a rigid shaft.

Combination tag. See anchor tag and roll tag.

Celluloid tag (Fig. 26). A strip of celluloid inserted into the body cavity.

Dart tag (Figs. 27a – c). A tubular tag with a single or double barb at one end. There are many varieties of dart tag. Another example is the "POFI D–2" tag described by Yamashita and Waldron (1959) that is used on tuna. It has a single barb made of Lucite, 13/16 inch in length and 1/16 inch diameter. The body of the tag is a plastic tube (Fig. 43).

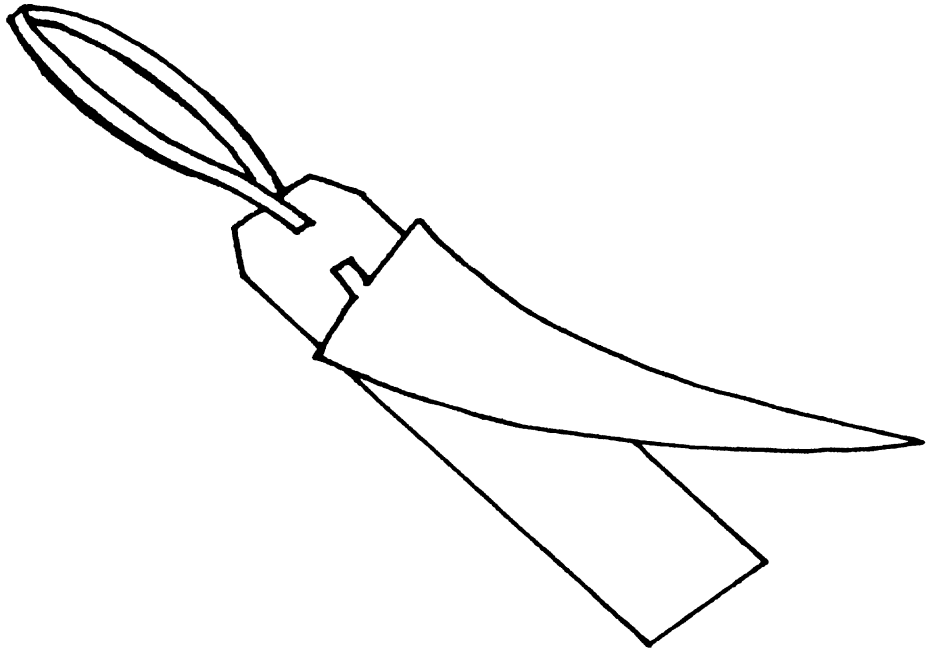


Fig. 20 - Albrechtsen (arrow) tag
(Redrawn from Jakobsson, 1970)

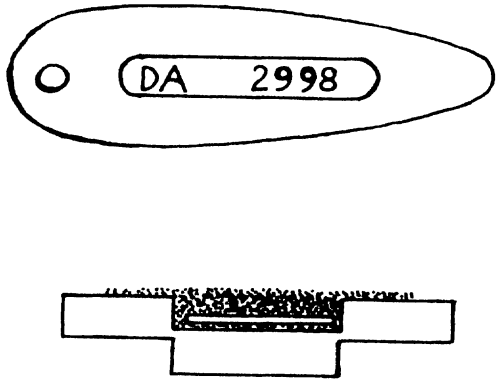


Fig. 21 - Alcathene tag: a) Top view
b) Section showing piece of metal embedded in wax
(Redrawn from Bertelsen, 1955)

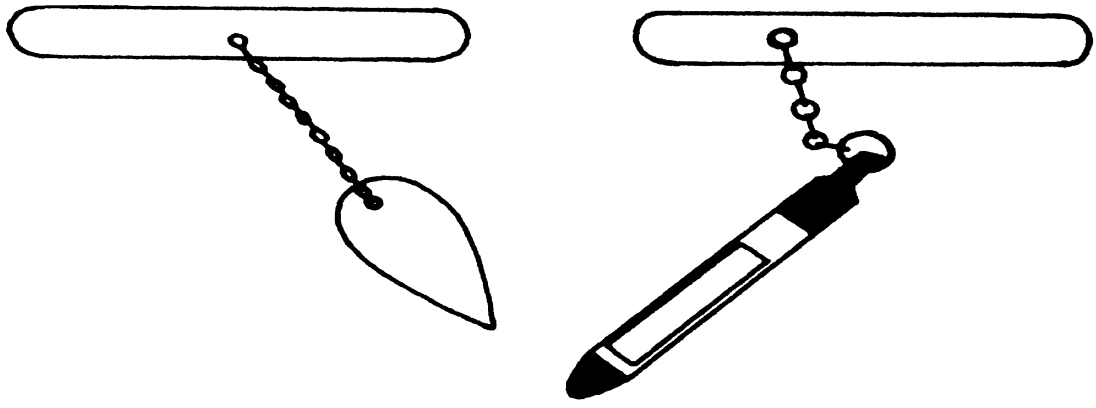


Fig. 22 - Anchor tag: a) with stainless steel plate and chain
b) with Lea tag and chain
(Redrawn from Jakobsson, 1970)

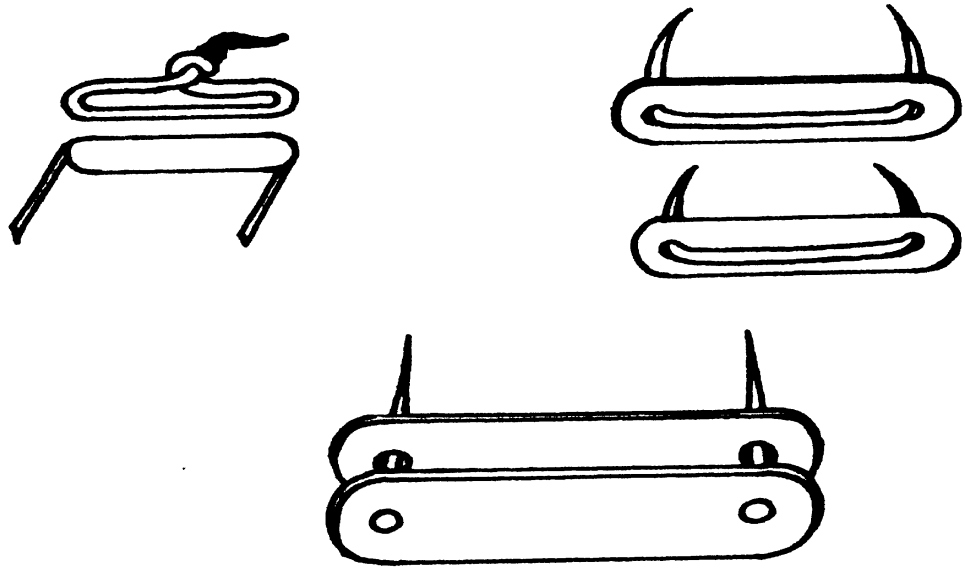


Fig. 23 - Archer tag (Redrawn from Jakobsson, 1970)

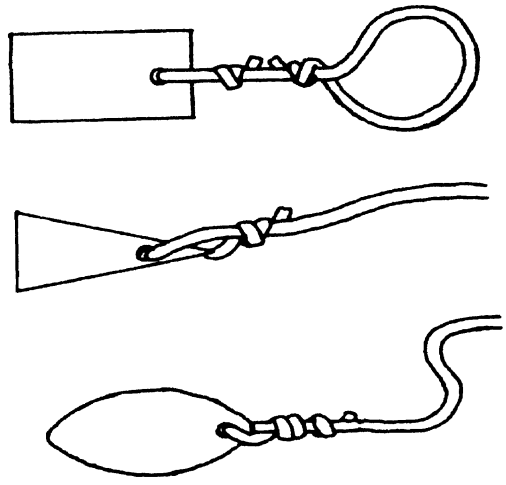


Fig. 24 - Atkins tags (Redrawn from Jakobsson, 1970)

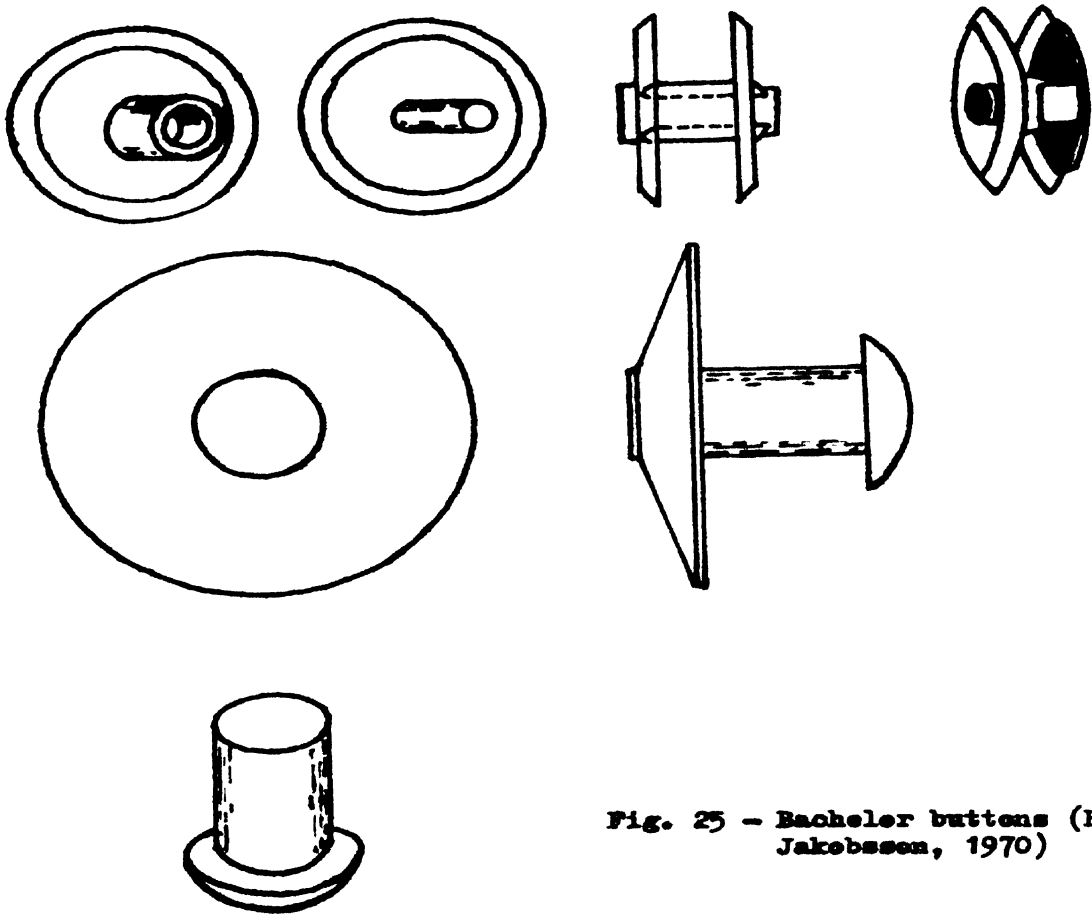


Fig. 25 - Bachelor buttons (Redrawn from Jakobsson, 1970)

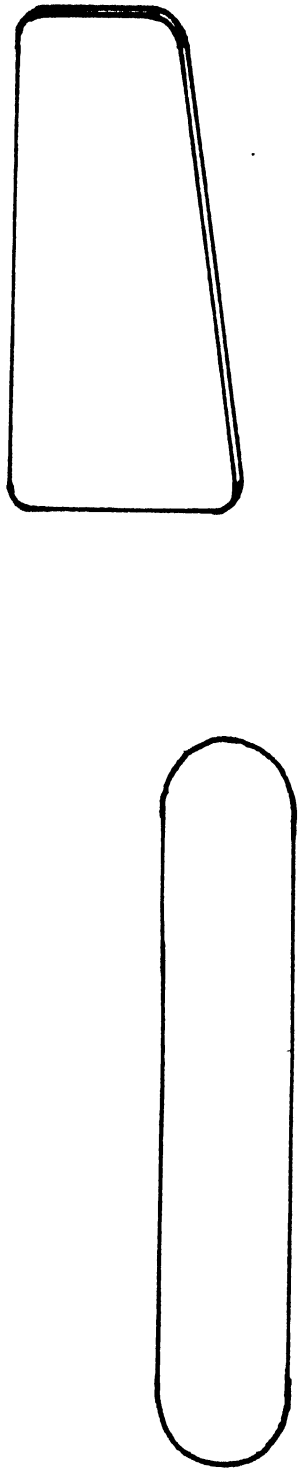


Fig. 26 - Celluloid tags (Redrawn from Jakobsen, 1970)

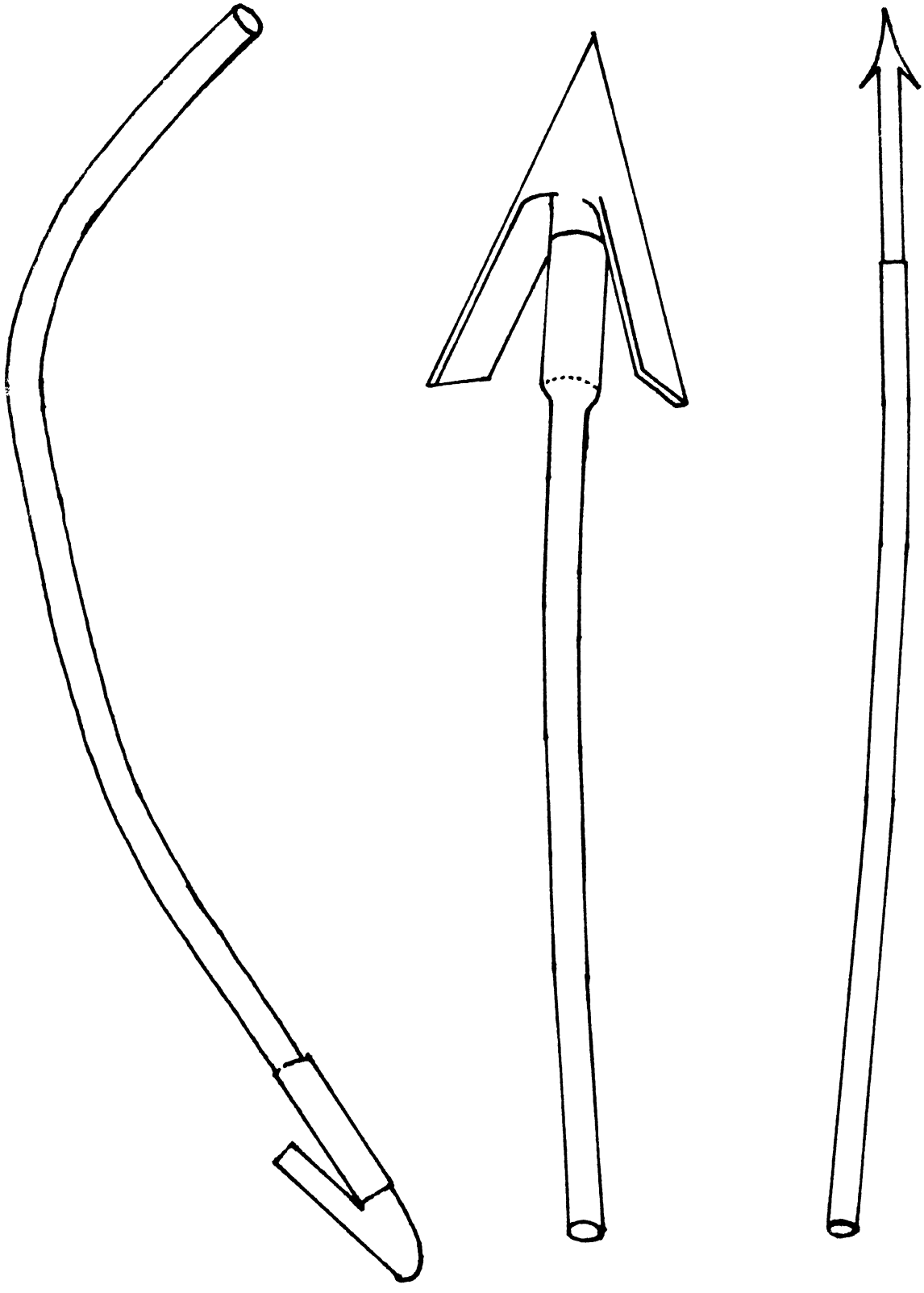


Fig. 27 - Dart tags: a)
b) dart tags used on tuna (Redrawn from Jakobsson, 1970)
c)

Flag tag (Fig. 28). These are usually made of PVC sheet, rectangular in shape, with the corners rounded. They are often red, yellow or orange in colour.

Heincke ring (Fig. 29a). According to Jakobsson (1970) this consisted of an aluminium strip 20 x 6 mm x 0.75 mm thick. It was used from 1902 to 1904 for marking plaice.

Heincke stud (Fig. 29b). This consists of a disc to which a rigid shaft is fastened. The shaft has a pointed knob on the end over which the second disc of rubber is slipped. It was for plaice marking from 1903 to 1911 (Jakobsson, 1970).

Hydrostatic (Lea) tag (Fig. 30). A tag developed by Einar Lea. It consists of a hollow celluloid tube with a small celluloid rod at each end. One end of it is flattened and contains a small hole for the attachment of a wire or thread. Its specific gravity is very similar to that of sea water (Jakobsson, 1970).

Internal tag (Figs. 31a, b). Typically an elongated strip of celluloid, plastic or magnetic material inserted subcutaneously or into the body cavity (Fig. 26b, c).

Lea tag. See hydrostatic tag (Fig. 30).

Magnetic wire. A small segment of .25 mm diameter ferro-magnetic wire identified by means of a colour code. The tags are segments 1 mm long. Individual tag identification is based on a colour code utilizing narrow longitudinal stripes of coloured epoxy ink (.05 mm width). (Jefferts, Bergman and Fiscus, 1963).

Petersen tag (Fig. 32). Two circular discs connected by a wire or pin passing through some part of the fish.

Polythene tag (Figs. 33a - c). Two boat-shaped sections of plastic, cemented together and containing a numbered strip of paper which can be read through the translucent material of the tag (Parrish and McPherson, 1955).

Roll tag (Fig. 34). This is a kind of anchor tag and consists of three parts. It has an internal anchor, a "roll" and a locking bead. Anderson and Bagge (1963) describe the anchor tag used for tagging plaice. The anchor consists of a plate, 25 mm long, 4 mm wide and 0.2 mm thick to which a nylon loop (0.4 mm) 37 mm long is attached. The roll is made of a band of plastic which is 165 mm long, tapered toward the ends so as to give the roll a hydrodynamic shape.

Spaghetti tag (Figs. 35a - c). A piece of plastic tube of varying length. In one form the tube is passed through the fish and then the free ends are either tied or joined (Fig. 35a, b). In another form the tube is fitted with a nylon anchor that holds the tag in the fish after it is inserted with a special tagging gun (Fig. 35c). This is really an anchor tag, therefore, but it is usually called a spaghetti tag, or sometimes a Dennison tag (after a manufacturer of the gun, which rapidly inserts tags one by one from a clip of tags loaded into it.)

Strap tag (Figs. 36a, b). A flat metal strip. One end of the strap is pointed and engages with a hole in the other end of the tag when the tag is squeezed closed.

Streamer tag (Figs. 37a, b). A long thin tag of highly flexible material. Usually made of very thin vinyl plastic sheet.

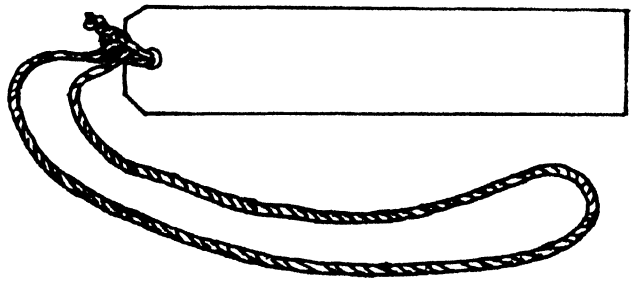


Fig. 28 - Flag tag with nylon loop attachment (Redrawn from Jakobsson, 1970)

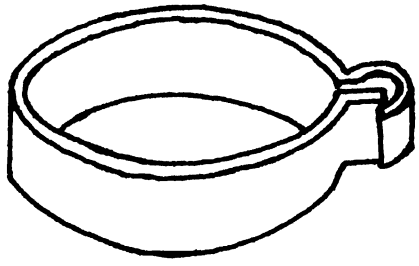


Fig. 29a - Heincke ring (Redrawn from Jakobsson, 1970)

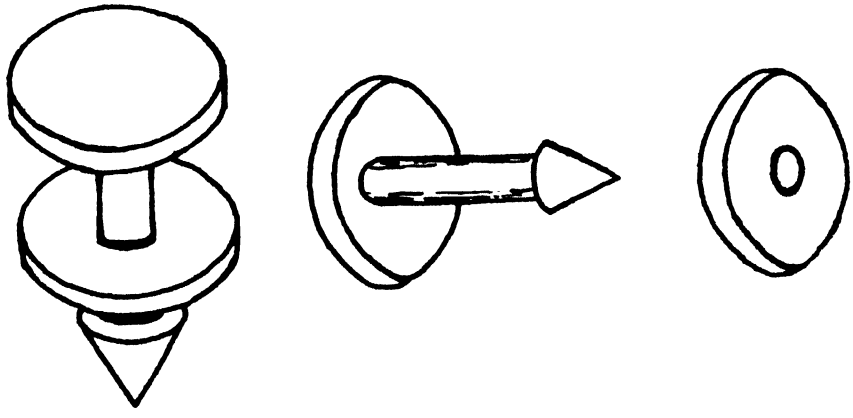


Fig. 29b - Heincke stud (Redrawn from Jakobsson, 1970)

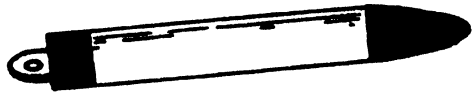
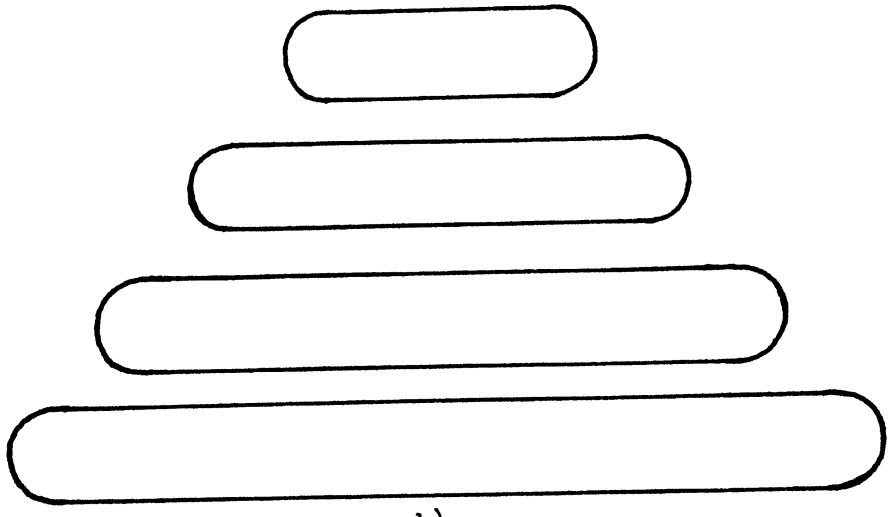


Fig. 30 - Hydrostatic (Lea) tag

a)



b)

Fig. 31 - Internal tags: a) Magnetic steel tag for internal use) (Redrawn from
b) Plastic tags for internal use) Jakobsson, 1970)

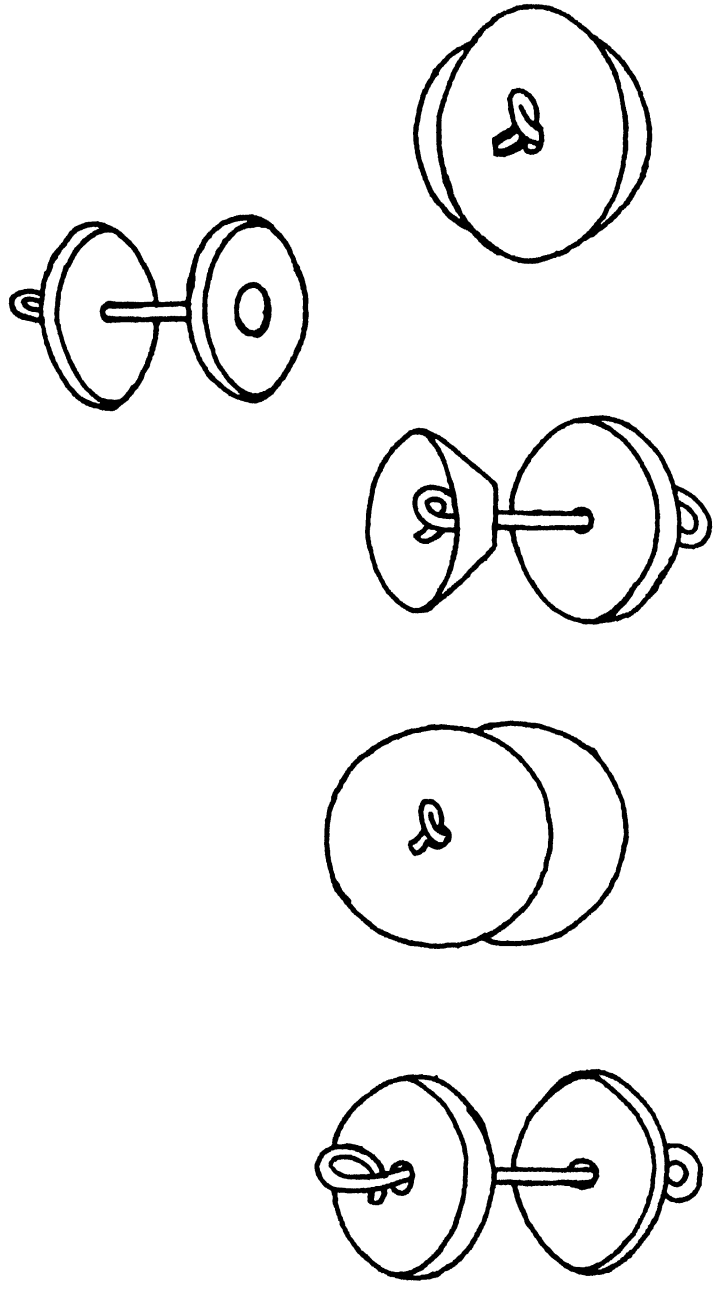


Fig. 32 - Petersen tag (Redrawn from Jakobsson, 1970)

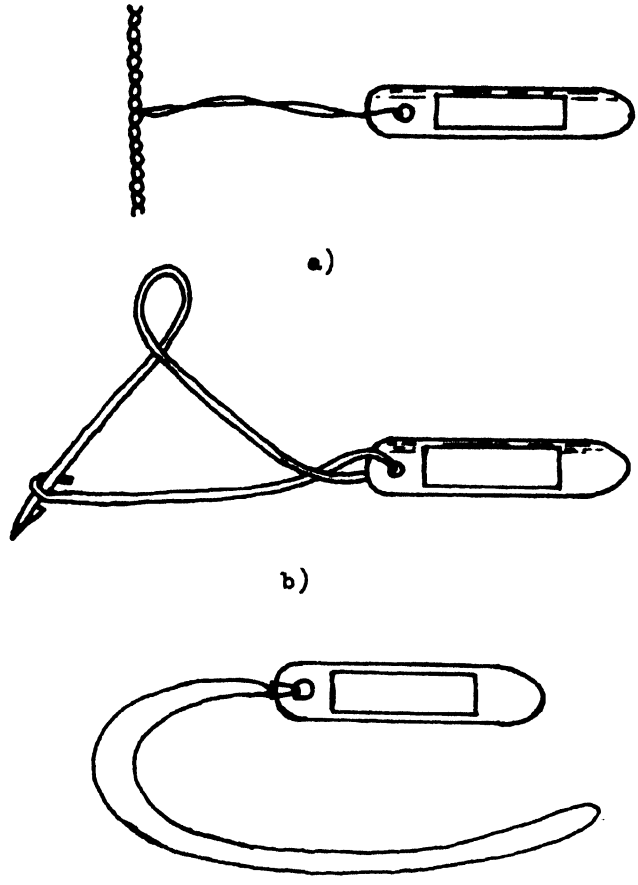


Fig. 33 - Polythene tag: a) with toggle attachment
b) with 'safety-pin' modification of Lea bridle attachment
c) with nylon loop attachment
(Redrawn from Jakobsson, 1970)

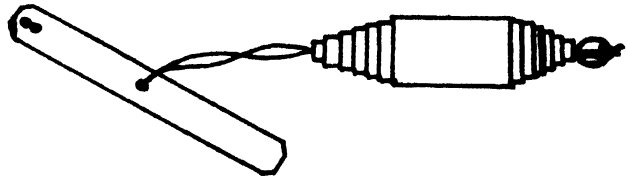
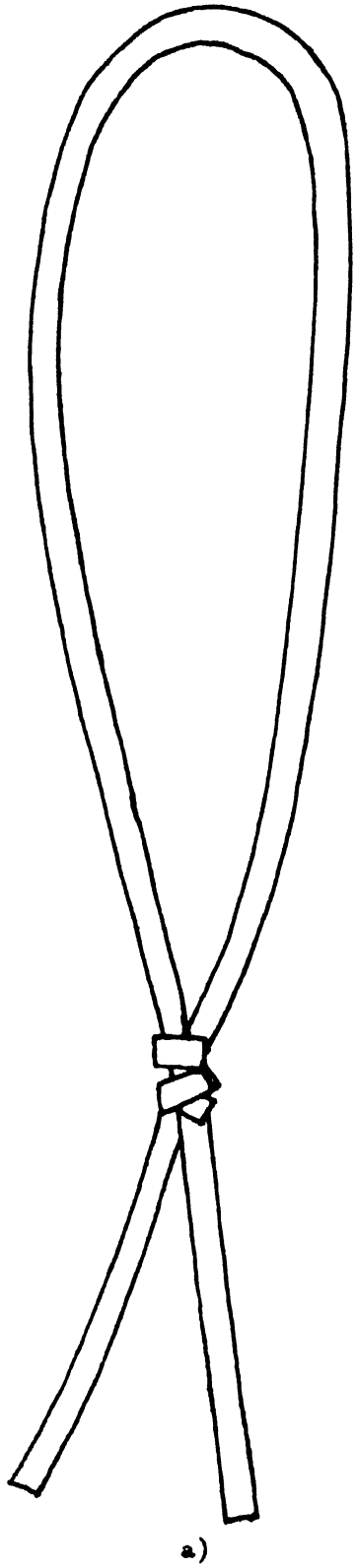
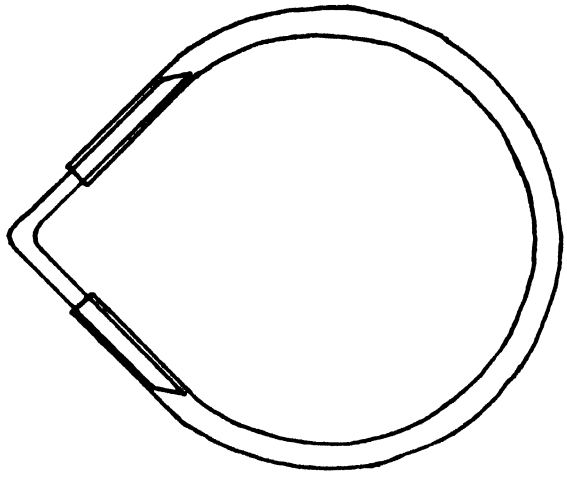


Fig. 34 - Roll tag (Redrawn from Jakobsson, 1970)



a)

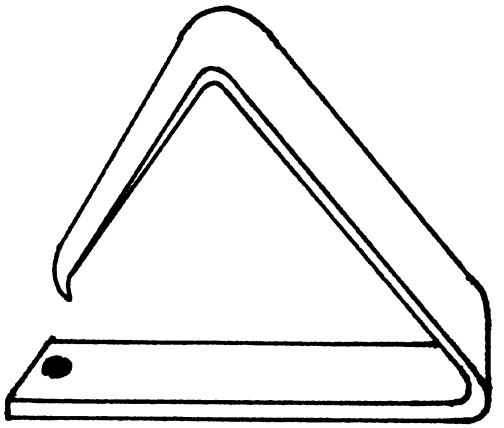


b)

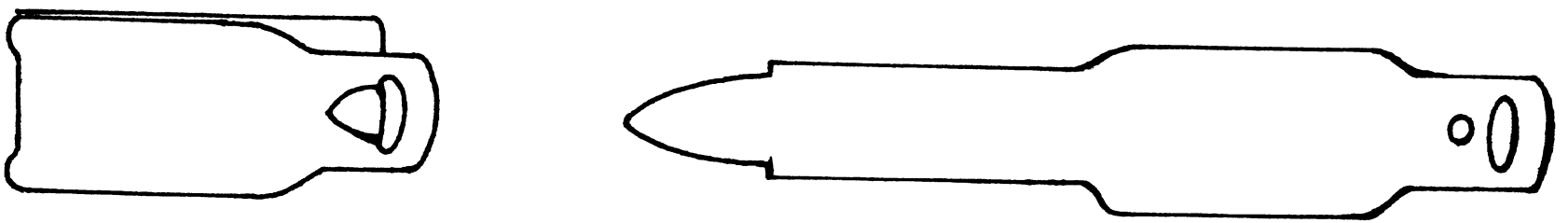
c)

Fig. 35 - Spaghetti tag:

a) showing ends of tag joined by tying
b) showing ends of tag joined with L-shaped piece of stiff polythene
c) showing T-bar nylon anchor



a)



b)

Fig. 36a and b - Strap tags (Redrawn from Jakobsson, 1970)

Fig. 37a and b - Streamer tags used on shrimp (Redrawn from Marullo et al., 1976)
a) tag with needle attached ready for use
b) tag with needle broken off after insertion

3.2 Attaching the tags

Tags can be attached directly or indirectly with the use of special needles or applicators.

3.2.1 Direct attachments

Tags that are attached with wire can be attached directly if the wire is strong enough to push through the flesh of the fish without bending. For example, Kotthaus (1963) tagged soles with Petersen discs connected by silver or titanium wire. Titanium wire has the advantage of being light but its high pliability makes it difficult to push through the musculature of the fish. Kotthaus notes that to some extent, this can be overcome by cutting the wire at an angle so that the ends become tapered.

The Petersen tag is normally attached directly. Fig. 13 shows a Petersen tag being attached to the operculum of a haddock. The pin is threaded through the centre of one disc and then pushed through the operculum from the inside. The second disc is then threaded on the projecting point of the pin. The surplus part of the pin is cut off and the remainder twisted into a loop, or bent over using long nosed pliers (Jensen, 1958). Figs 38a - h show the attachment of a Petersen tag to a plaice.

Hydrostatic (Lea) tags may be attached directly with a wire or a "Lea bridle". The bridle has two eyes and is secured to the fish by a strong pin (Fig. 39). The pin is passed through one eye, through a soft part of the fish (typically the dorsal musculature) and through the eye at the other end of the bridle. The surplus part of the pin is then twisted into a loop with long nosed pliers. In one modification, the bridle is made in the form of a safety pin, the pin of which is thrust through the dorsal musculature of the fish and then clipped into position (Figs. 40a - c).

Parrish and McPherson (1955) developed a toggle attachment consisting of a wire anchor toggle attached to the tag with a loop of nylon thread. The toggle is made by twisting two strands of stainless steel wire tightly together and incorporating a loop of nylon thread during the twisting process. A toggle formed in this way can be thrust through the soft parts of many species of fish without difficulty (Figs. 41a - c).

Fig. 38 - Attaching a Petersen tag to a flatfish
(Modified from illustration in Andersen and Bagge, 1963)

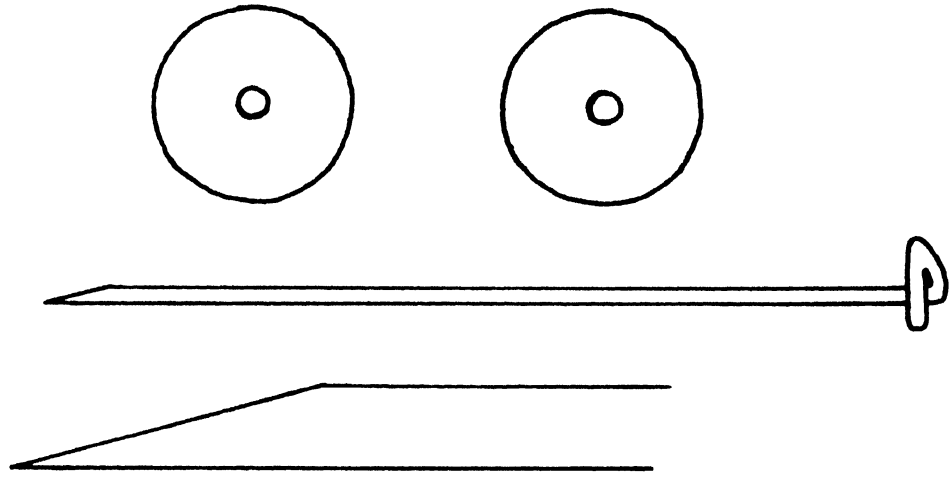


Fig. 38a - Two Petersen discs and tagging pin - also enlargement of end of pin shaped to facilitate penetration

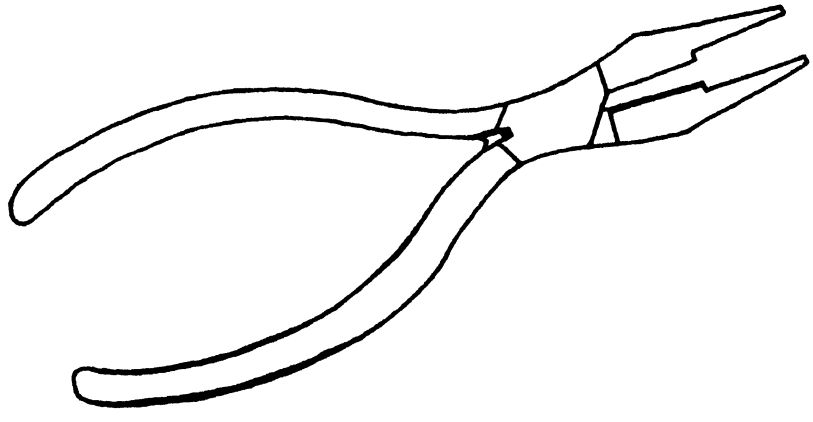


Fig. 38b - Thin-nosed pliers

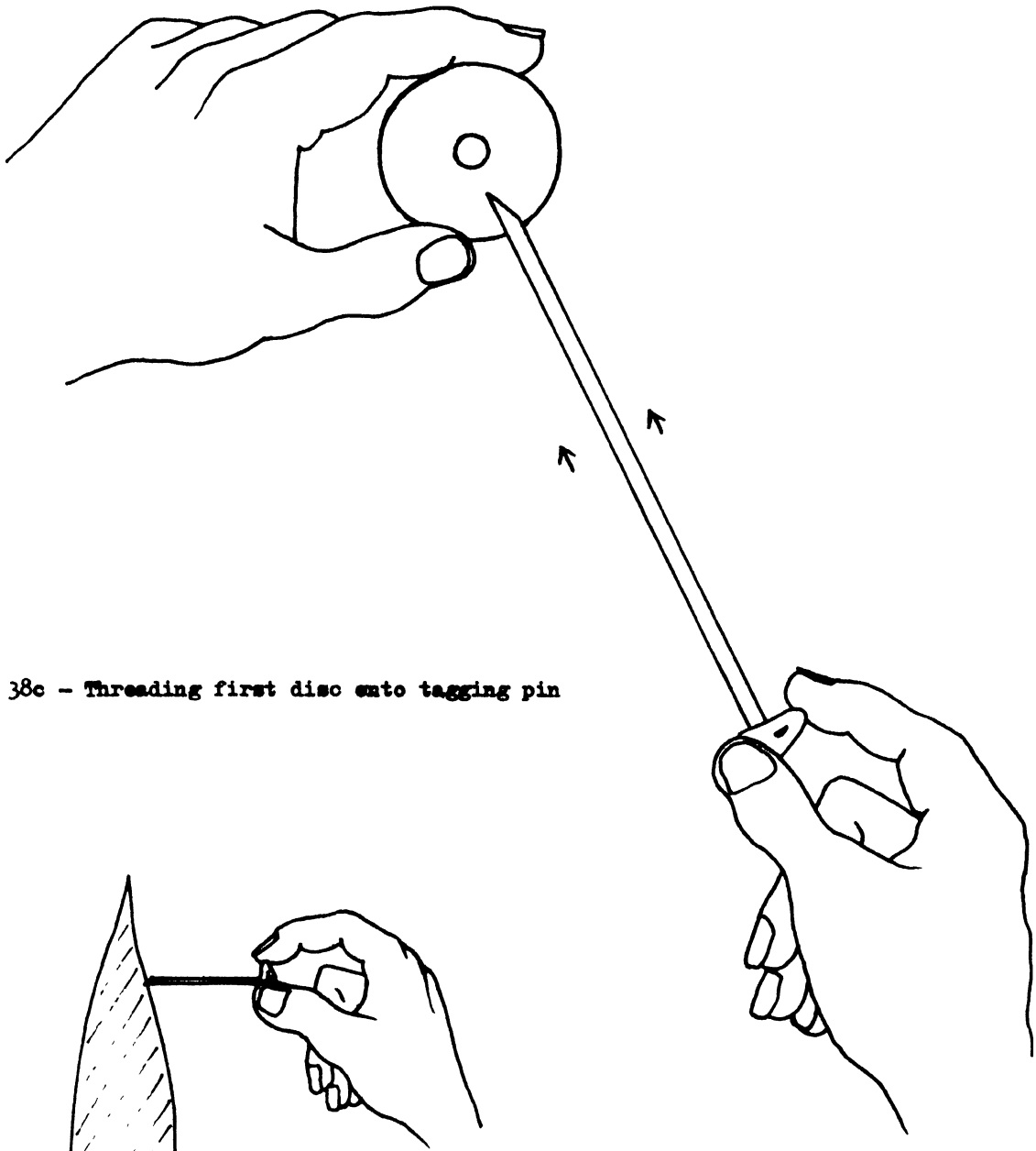


Fig. 38c - Threading first disc onto tagging pin

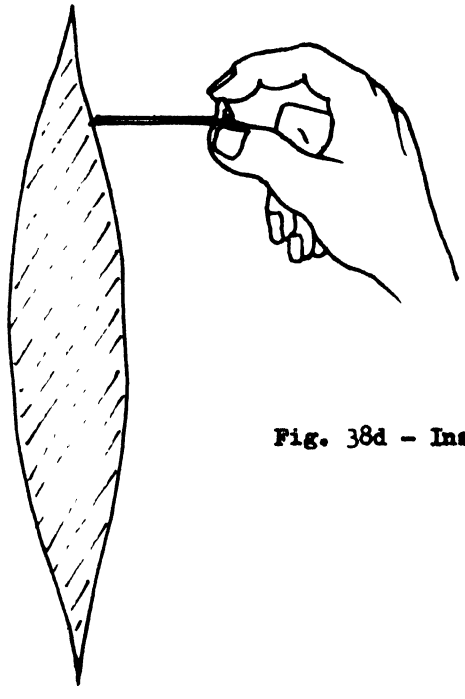


Fig. 38d - Inserting pin through fish

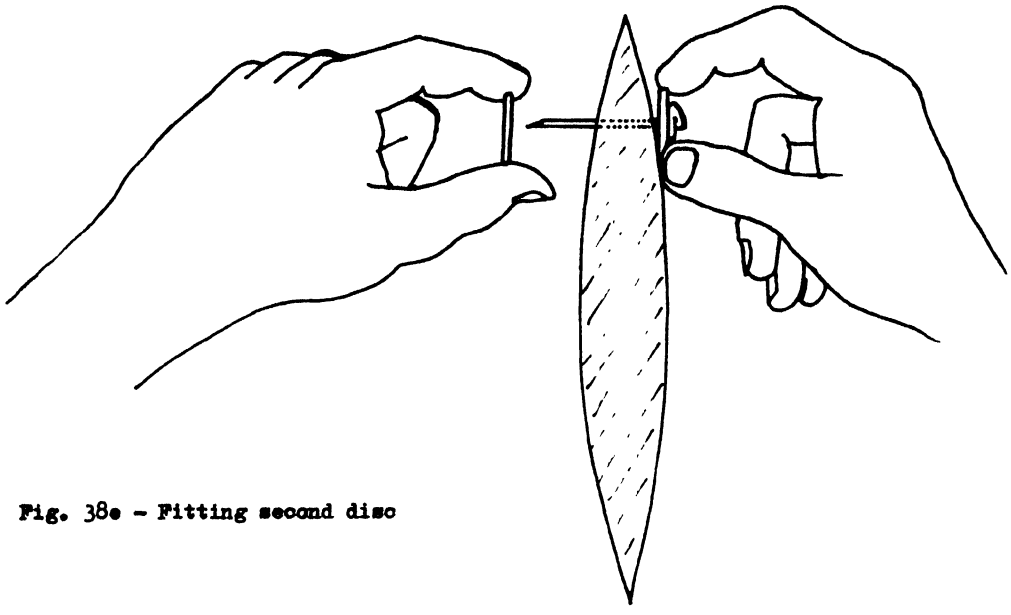


Fig. 38e - Fitting second disc

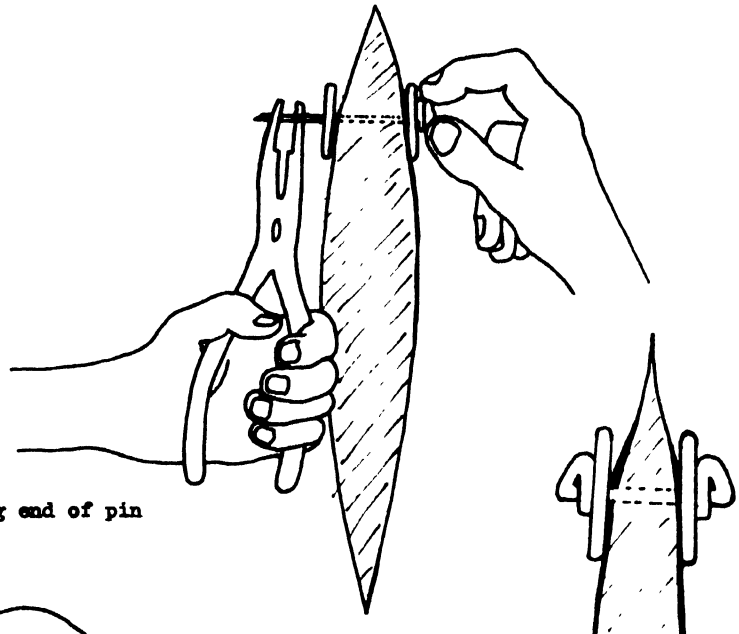


Fig. 38f - Twisting end of pin

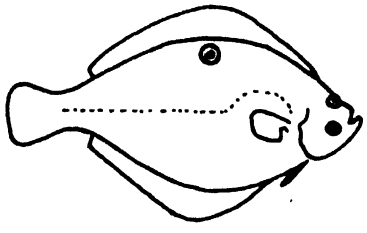


Fig. 38g - Tagging operation completed

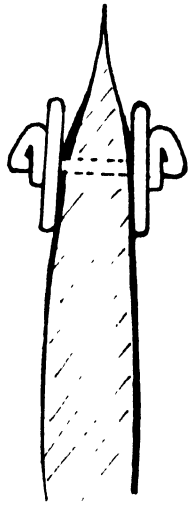


Fig. 38h - The tag in position

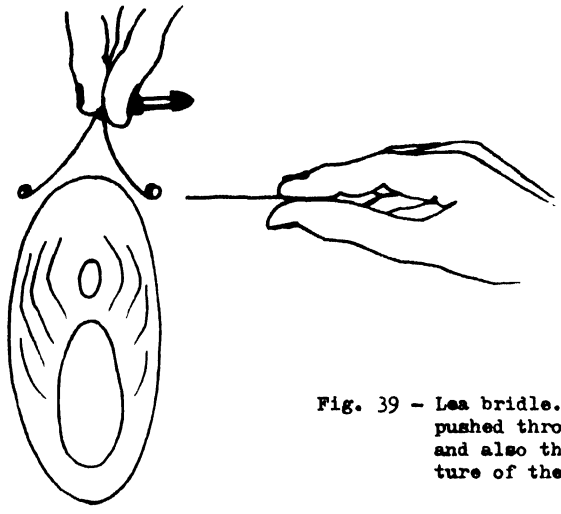


Fig. 39 - Lea bridle. The pin is about to be pushed through the eyes of the bridle and also through the dorsal musculature of the fish

Fig. 40 - Attaching a 'safety-pin' modification of the Lea bridle

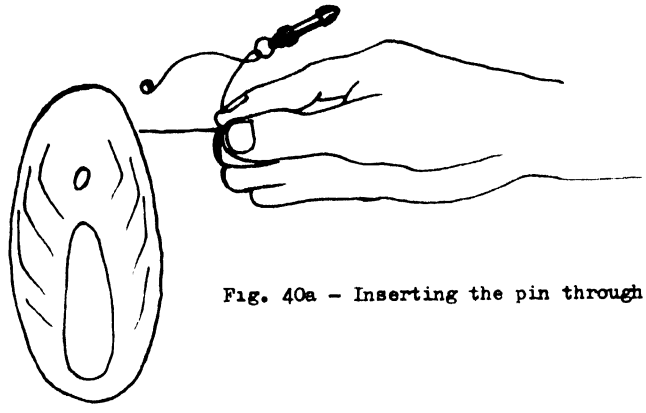


Fig. 40a - Inserting the pin through the fish

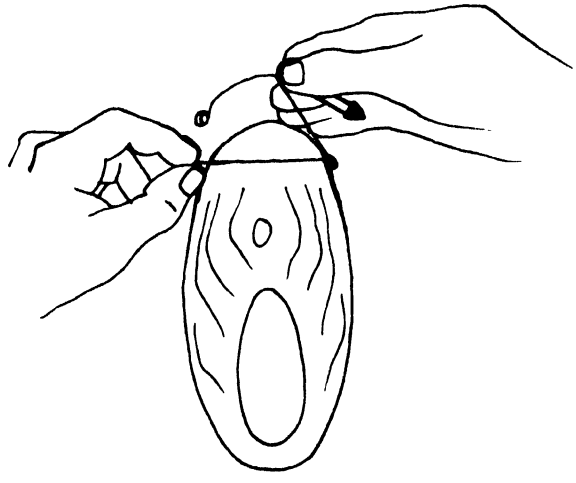


Fig. 40b - Clipping the end of the pin onto one side of the bridle

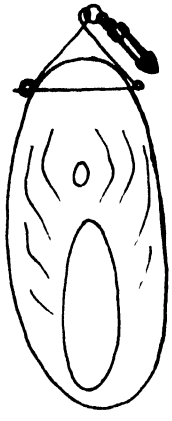


Fig. 40c - The tag in position

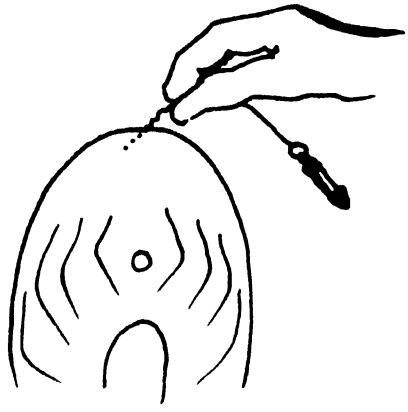


Fig. 41a - Pushing the toggle obliquely through the fish

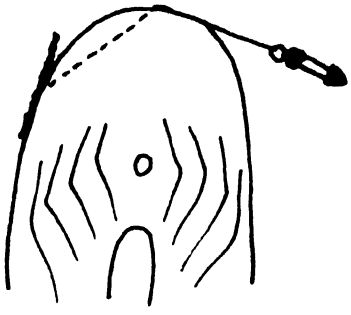


Fig. 41b - Section of fish with tag and toggle attachment in position

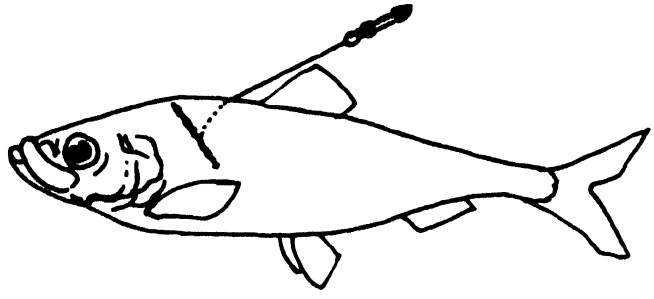


Fig. 41c - Side view of fish

Fig. 41 - Attaching a Lea tag with a toggle attachment

Strap tags are typically attached to the operculum or jaw of a fish. The tag is closed using clenching pliers (Fig. 42), so that the point at one end of the tag passes through the soft part of the fish and locates securely in the hole at the other end of the tag.

3.2.2 Use of a hollow needle

When dealing with thin wire attachments, or with large fish with tough skins, a hollow needle may be necessary to facilitate tagging. Wise (1963) used a hypodermic needle for attaching Petersen discs to large cod. A hypodermic needle is passed through the muscles just in front of the first dorsal fin. A wire bearing a Petersen disc is pushed through the inside of the needle. The needle is then pulled through the fish, free of the wire, and the second disc is placed over the free end of the wire which can then be cut to the appropriate length and twisted to hold the two discs firmly in place.

Dart tags, which have been developed particularly for tuna tagging, are normally applied with a hollow needle. The tag is fitted into a stainless steel needle the end of which is cut at an angle of 45^{o} for ease of penetration. This is driven into the back of the fish so that the barb of the tag lodges behind a neural spine of one of the bones at the base of the dorsal fin, thus anchoring the tag in the fish. The needle is then withdrawn (Yamashita and Waldron, 1959) (Fig. 43).

Lawler (1963) describes a spring stainless steel attachment (Fig. 44). A number 16 syringe needle is inserted diagonally through the fish at an angle below the dorsal fin between the interneurals and through the skin on the other side. The spring end of the wire is compressed by being inserted into the hollow needle and the needle is withdrawn until the anchor, still within the needle, is in position between the interneurals. The tagger then grasps the tag and gives it a slight tug to release the anchor from the needle, causing the spring to open and leaving it securely anchored between the interneurals.

A method of tagging flatfish with a Petersen disc using a double injection needle with courlene monofilaments has been described by Rauck (1969) (Figs. 45a - c).

Hollow needles may be cleaned by soaking them successively in solutions of enzyme detergent and bleach and then rinsing them thoroughly with sea water (Bayliff, 1973).

3.2.3 Use of special needles

For attaching tags with a nylon thread, special needles are usually required.

Ancellin (1955) describes a method using a surgical needle. The needle is first passed through the fish. The nylon loop is then attached to the eye of the needle and by withdrawing the needle the nylon loop is pulled through the fish. The loop is then secured by hooking it into two special notches on the tag (Figs. 46a - c and 47a - d).

Nylon loops may also be threaded through the fish by using a needle with an "open eye". The nylon loop is hooked into the eye of the needle which is then passed through the body of the fish drawing the thread behind it. The needle may then be disconnected from the thread which may be tied and secured to the tag (Figs. 48a - e).

Spaghetti tags are inserted by fitting them onto the end of a special needle with a projection designed to fit into the hollow core of the tag (Figs. 49a - c). The needle is passed through the fish drawing the tag behind it and then pulled clear of the tag. The ends of the spaghetti may be secured with an overhand knot (Figs. 49d - f). Alternatively, to speed up the process, a metal clamp can be used to fasten the two ends of the tag to form a loop (Fig. 49g). Initially this was a small monel or stainless steel clamp applied by hand and fastened with ordinary pliers. Subsequently an automatic stapling device was employed (Broadhead, 1959) (Figs. 49h and 50).

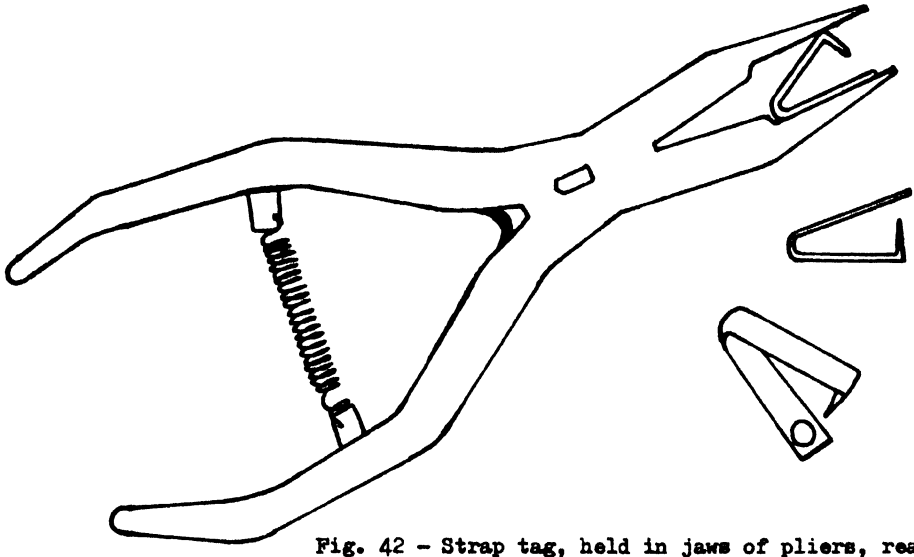


Fig. 42 - Strap tag, held in jaws of pliers, ready for clamping onto jaw or operculum (Redrawn from Thomson, 1963)

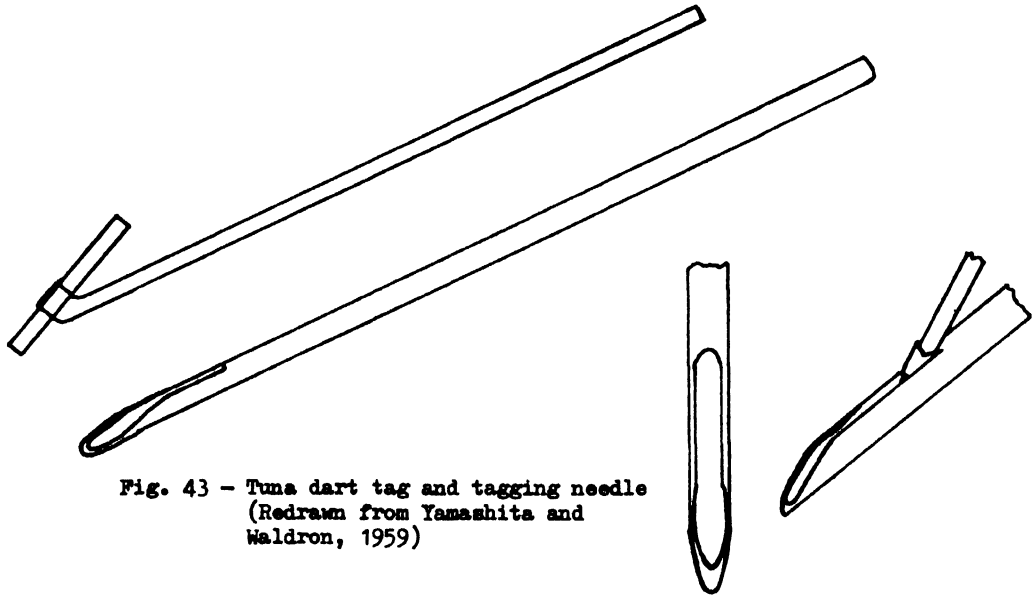


Fig. 43 - Tuna dart tag and tagging needle (Redrawn from Yamashita and Waldron, 1959)

Fig. 44 - Spring stainless steel attachment (Redrawn from Lawler, 1963)

Fig. 45 - Attaching Petersen discs with a double injection needle (Redrawn from Rauck, 1969)

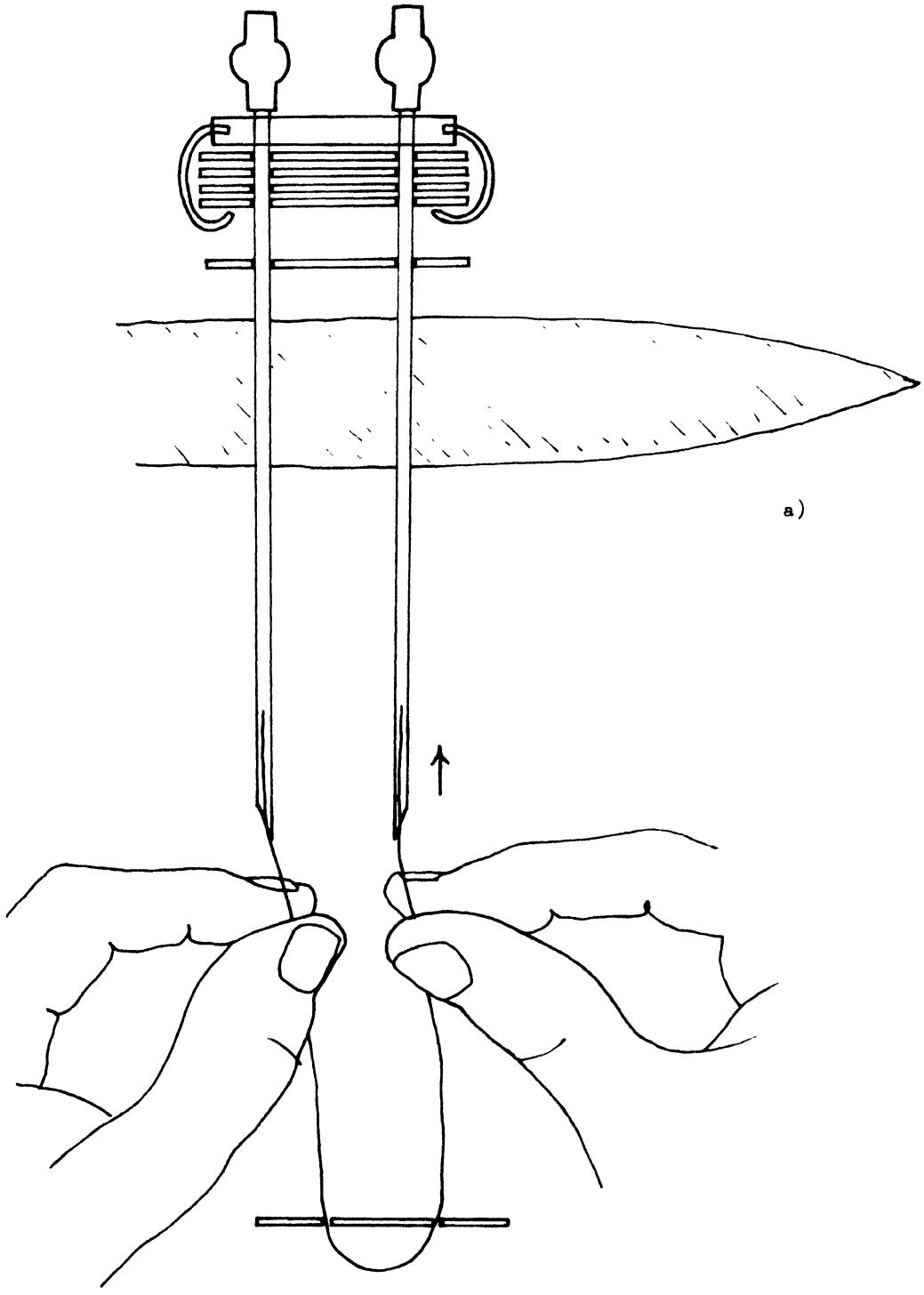


Fig. 45a and b - Threading twine through first disc and into the two needles

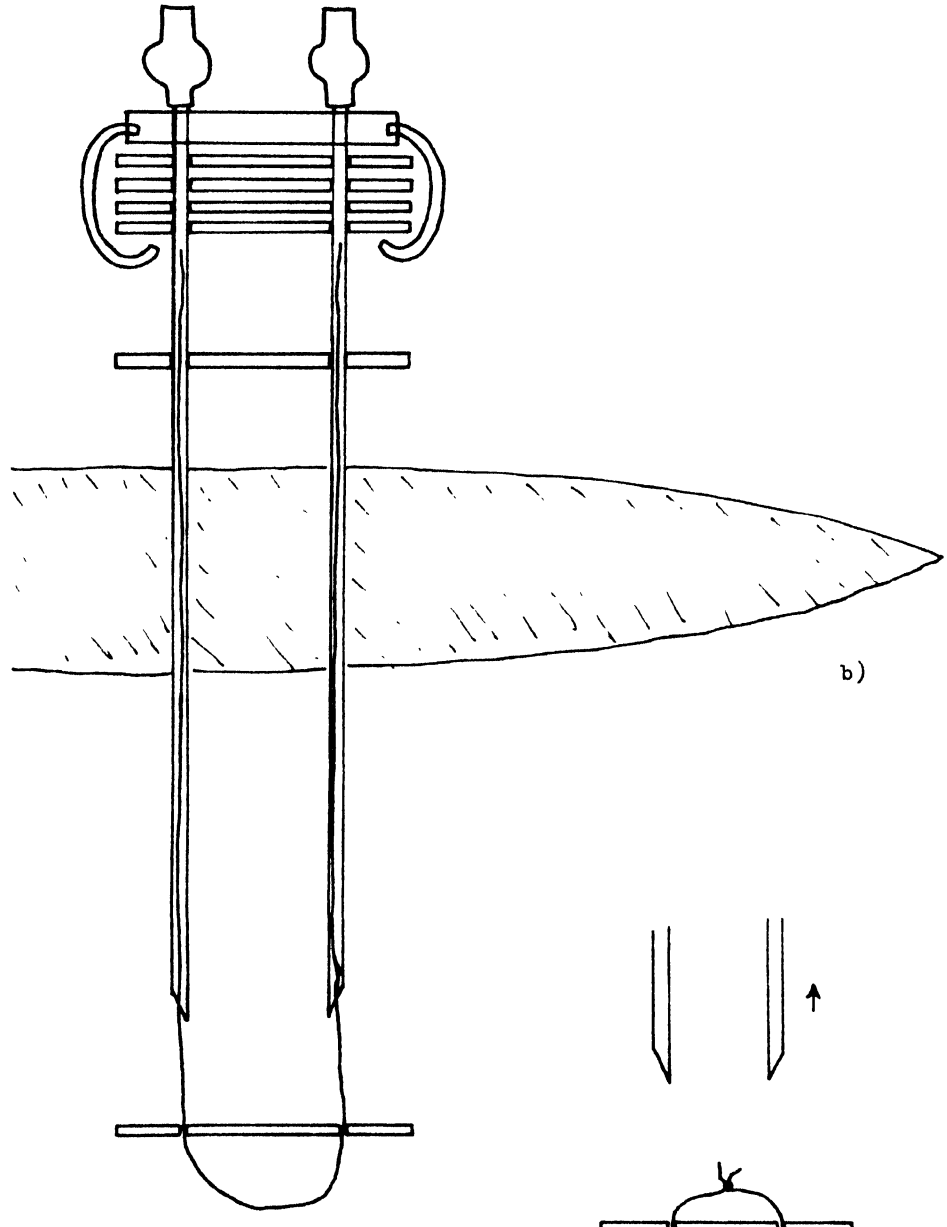


Fig. 45b (see 45a)

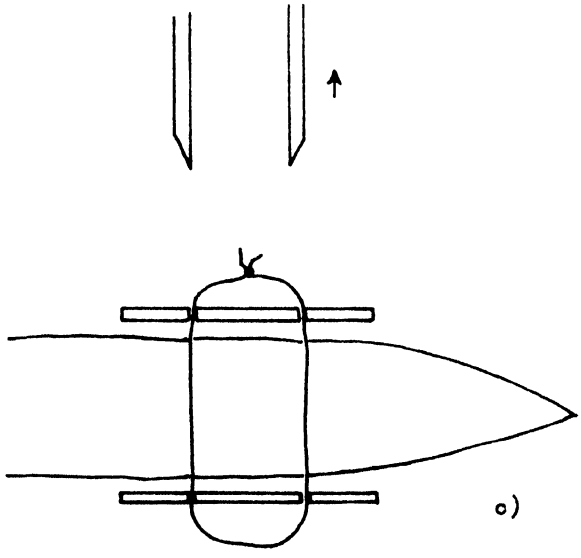


Fig. 45c - Needles withdrawn and both discs secured by tying twine

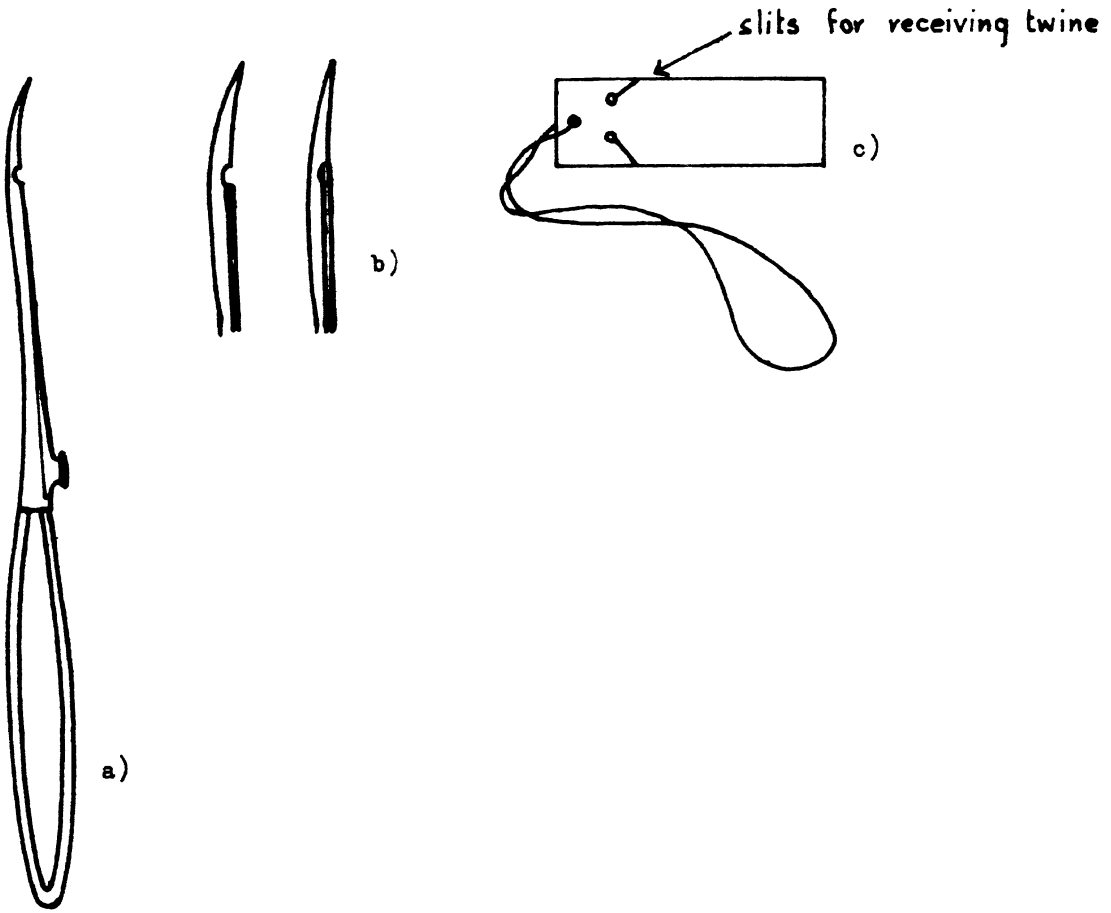


Fig. 46 - Surgical needle and rectangular tag (Redrawn from Ancellin, 1955)

a) Surgical needle

b) Eye of needle - open and closed

c) Tag with 2 slits for receiving twine

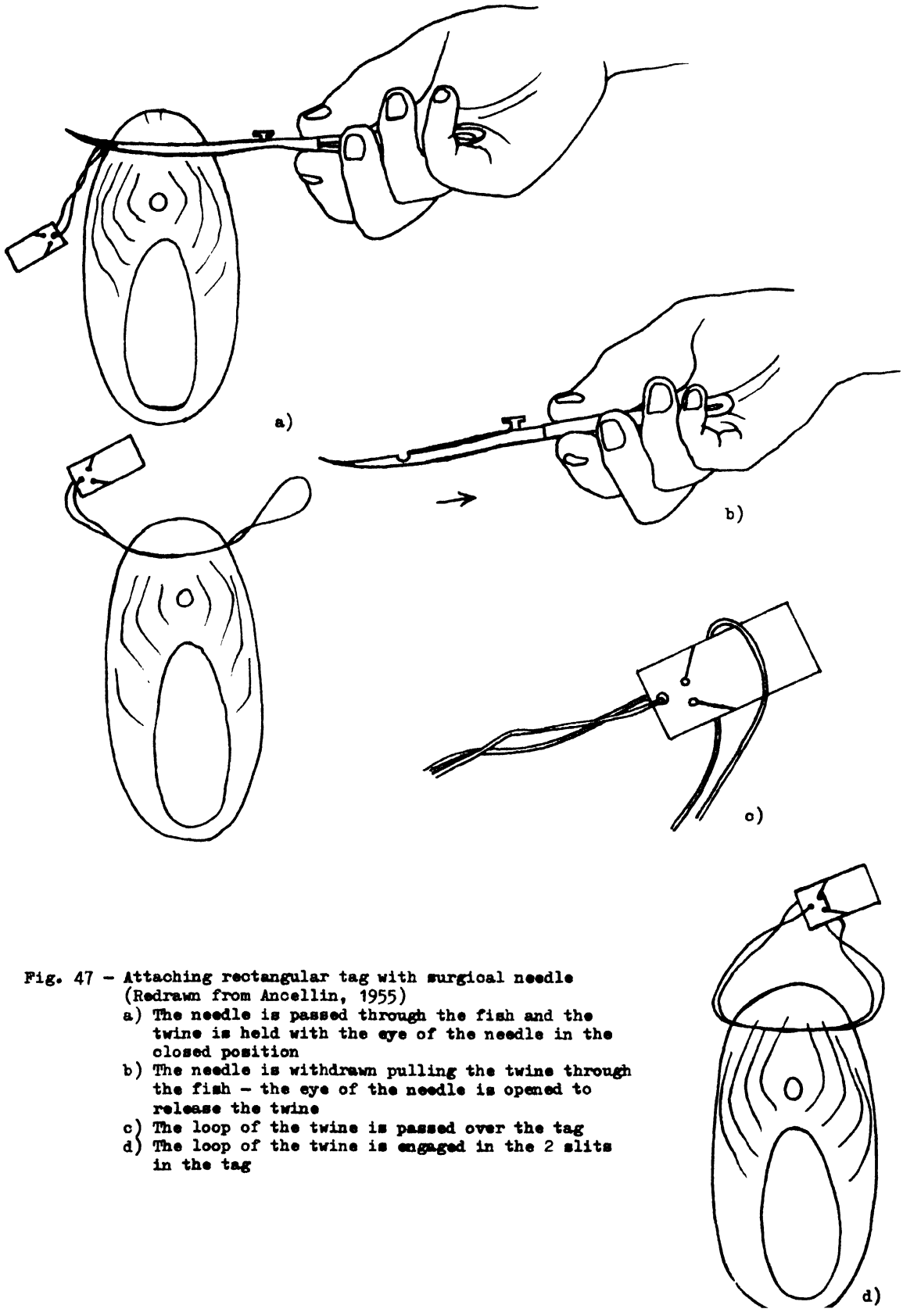
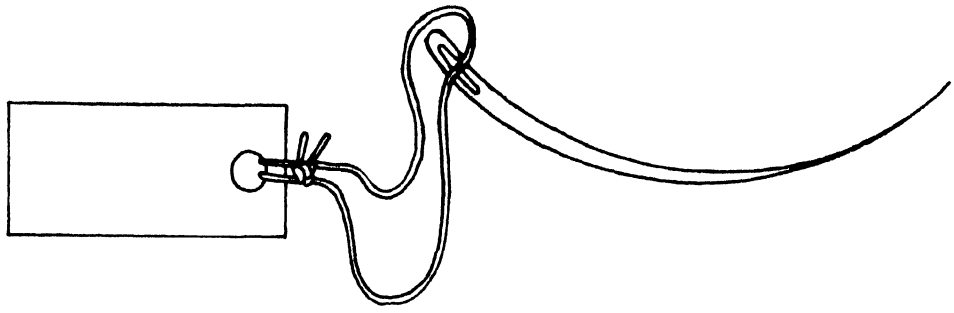
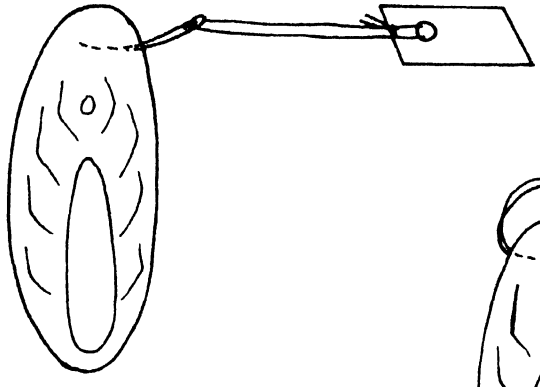


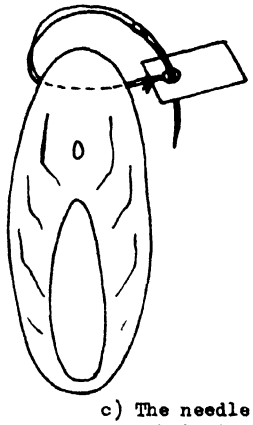
Fig. 47 - Attaching rectangular tag with surgical needle (Redrawn from Ancellin, 1955)
a) The needle is passed through the fish and the twine is held with the eye of the needle in the closed position
b) The needle is withdrawn pulling the twine through the fish - the eye of the needle is opened to release the twine
c) The loop of the twine is passed over the tag
d) The loop of the twine is engaged in the 2 slits in the tag



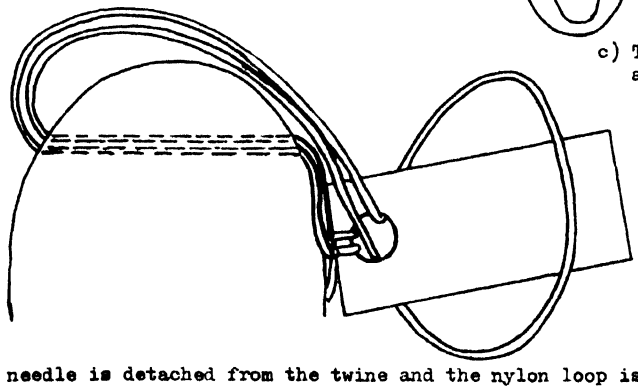
a) The loop of twine is engaged in the eye of the needle



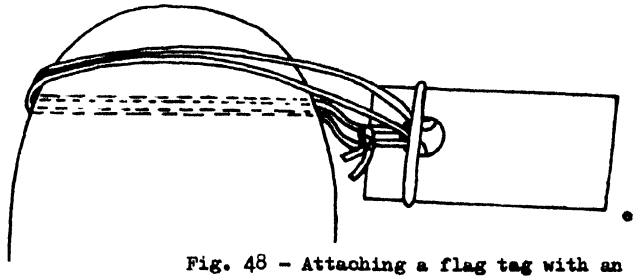
b) The needle is passed through the fish



c) The needle is passed through a hole in the tag



d) The needle is detached from the twine and the nylon loop is passed over the tag



e) The twine is pulled tight

Fig. 48 - Attaching a flag tag with an 'open-eyed' needle

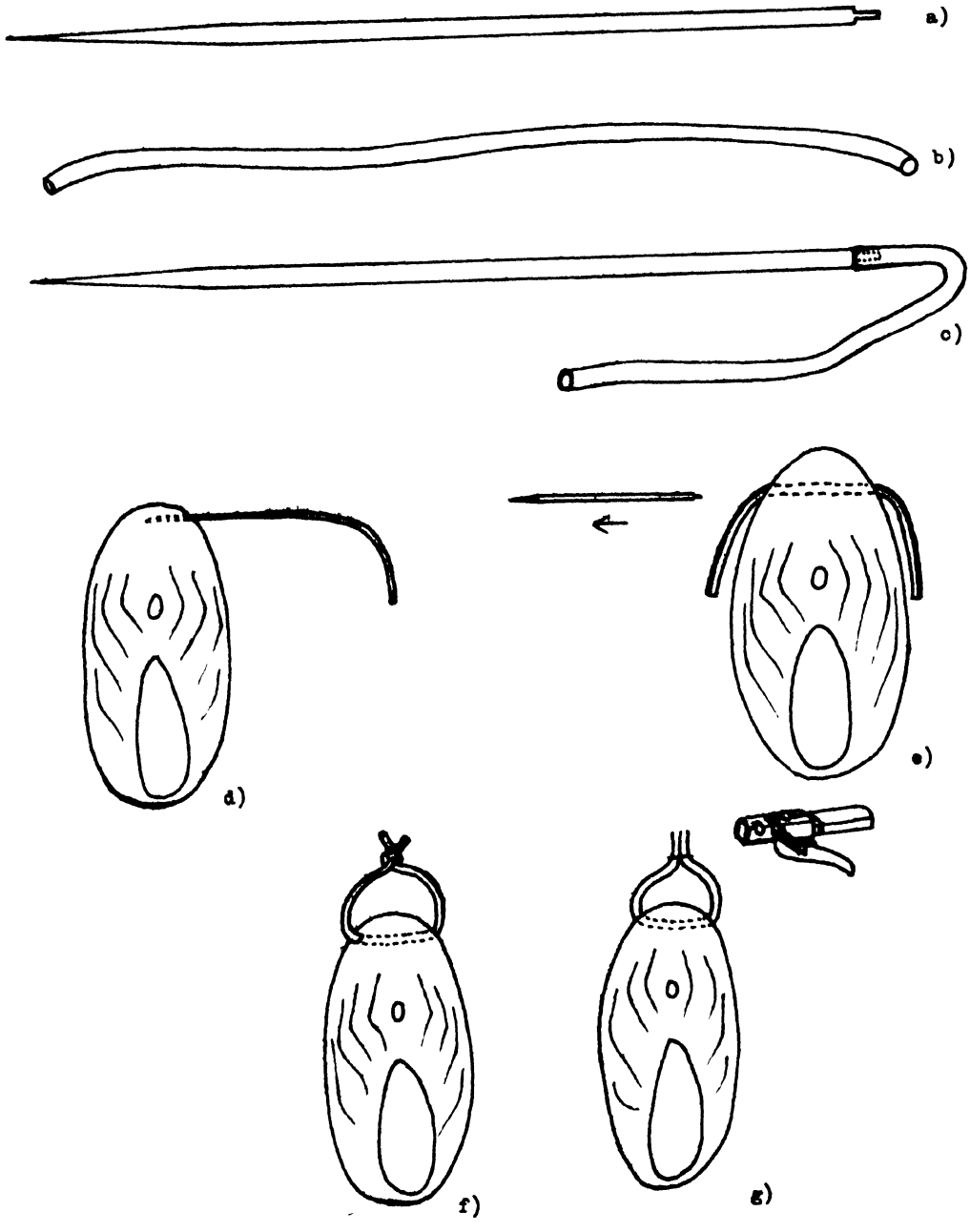


Fig. 49 - Attaching a spaghetti tag
- a) Special needle
- b) Spaghetti tag
- c) Tag fitted onto needle
- d) Inserting the needle through the fish
- e) The tag through the fish and the needle detached
- f) The ends of the tag tied
- g) Alternatively the ends can be stapled using a special gun (Fig. 49h) - see Fig. 50 for enlargement of stapling gun

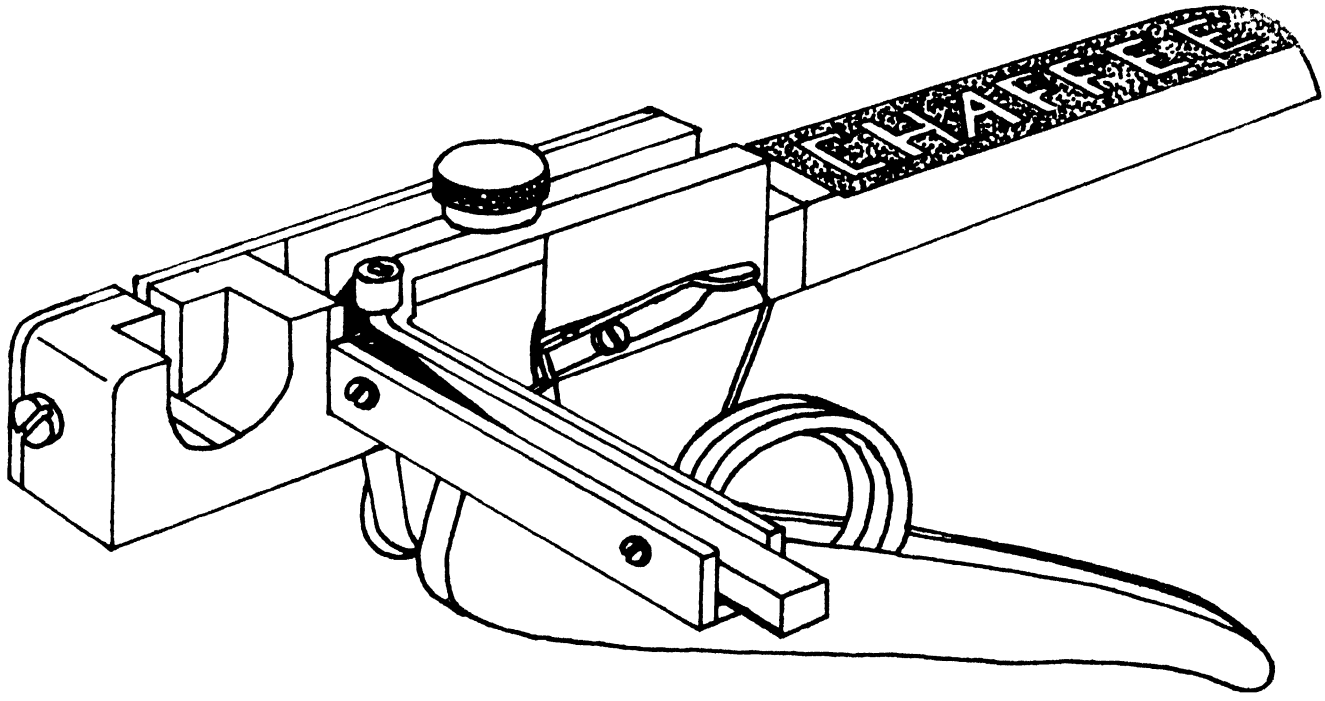


Fig. 50 - Stapling gun for securing the ends of a spaghetti tag (Redrawn from Broadhead, 1959)

Fritz (1963) describes a tag used for silver hake. It consists of an 8 inch piece of yellow vinyl plastic tubing (spaghetti type) with an Atkins tag tied at one end. The other end is inserted through the flesh of the dorsal musculature and knotted with a figure of eight knot. Fritz notes that this can be a very conspicuous tag (Figs. 51a - d).

Plastic streamers or narrow plastic tags also require a needle for inserting through the flesh. Williams (1963), for example, shows a plastic arrow tag sewn through the body of a sole (Fig. 52). Strips of vinyl in the form of streamers have also been used as tags (Fig. 37). These can be sewn onto the fish as described for the arrow tag above. These may be used alone or in conjunction with other tags to make them more conspicuous.

Where nylon loops are used various methods of attachment can be employed. Tags may be secured by tying, or by looping the nylon over the tag which may or may not have special notches to receive it as described by Ancellin (Fig. 46c). Parrish and McPherson (1955), working with herring, noted that tag loss could be reduced by using a double nylon loop at the point of attachment of the tag.

3.2.4 Special applicators

A number of special applicators have been devised to facilitate tagging. Rauck (1969), for example, describes a tagging gun for attaching plastic discs with a nylon attachment. The gun takes clips of nylon monofilaments (2.0-2.5 cm in length) with T-bars at each end.

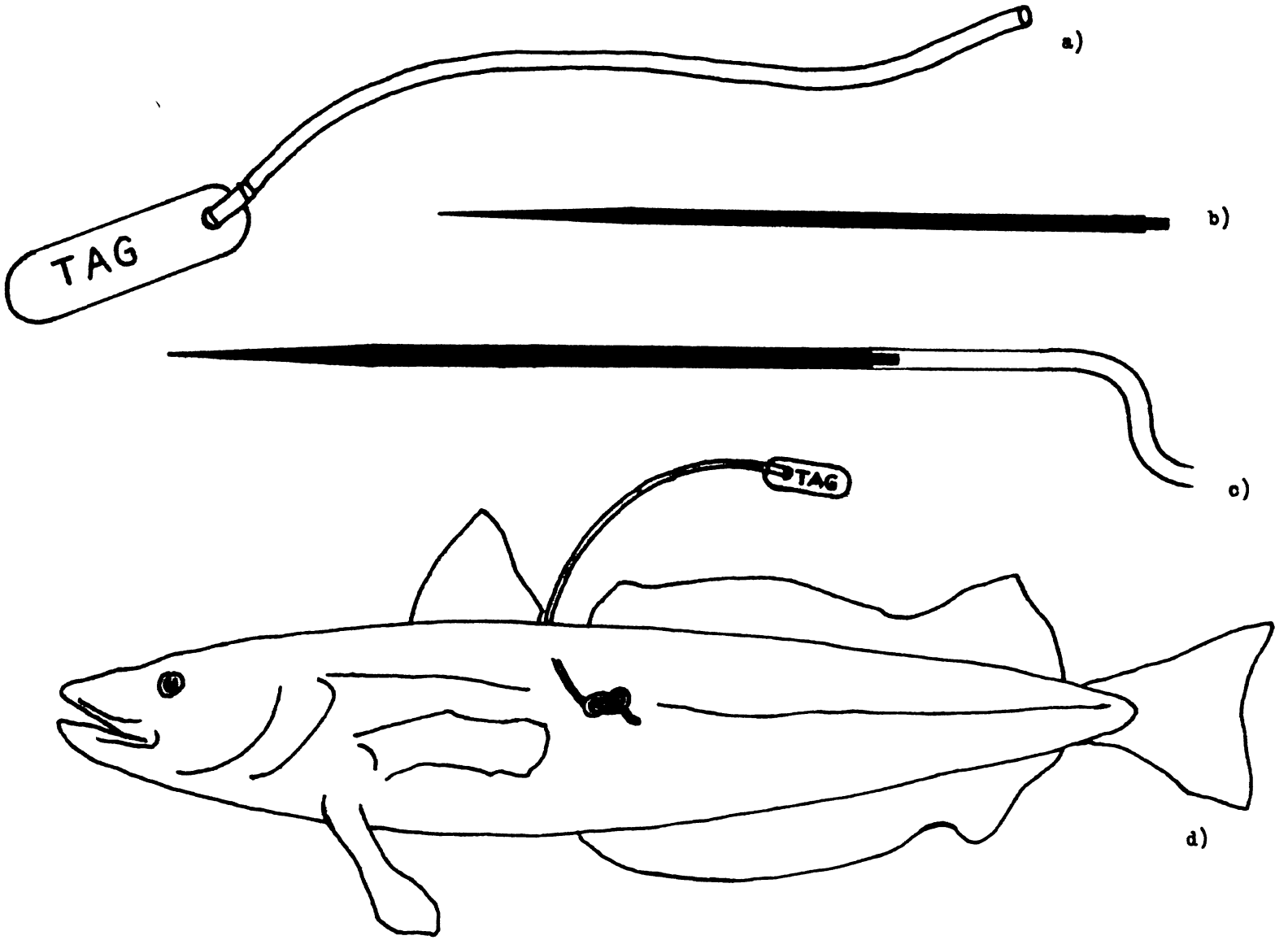


Fig. 51 - Tag used on silver hake (Redrawn from Fritz, 1963)

a) Yellow vinyl tubing with Atkins tag tied at one end
b) Tagging needle
c) Tag fitted onto needle
d) Tag in place

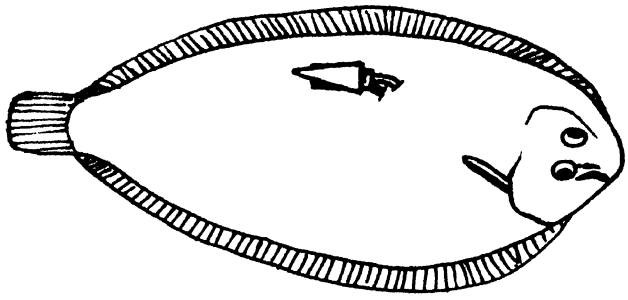
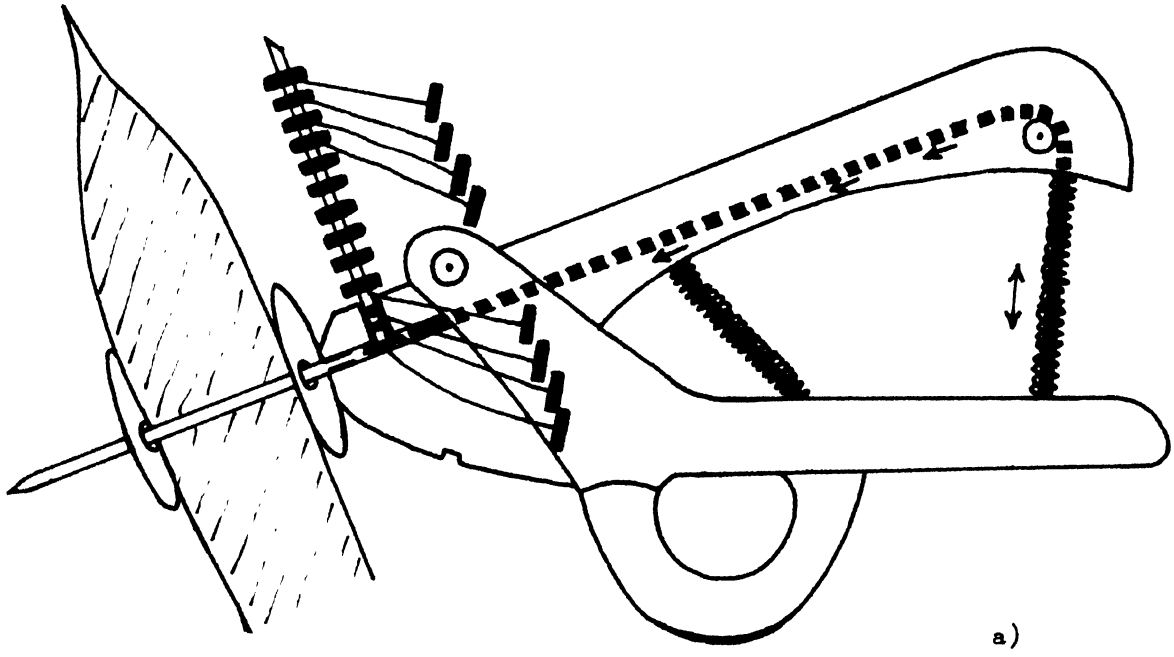
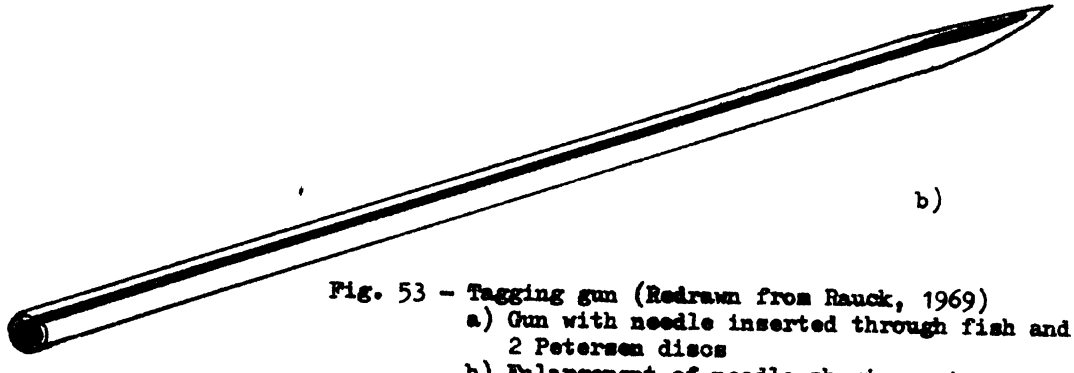


Fig. 52 - Arrow tag attached to sole (Redrawn from Williams, 1963)



a)



b)

Fig. 53 - Tagging gun (Redrawn from Rauck, 1969)
a) Gun with needle inserted through fish and 2 Petersen discs
b) Enlargement of needle showing cut-away channel

A disc is inserted onto the injection needle. The needle is pushed through the dorsal musculature and a second disc is threaded over the needle. By compressing the handle of the gun, one of the T-bars is torn off the clip and pushed by a ram lengthwise through the slotted needle and through the two discs. As the needle is withdrawn the T-bars on the ends of the tag twist to lie outside and parallel to the discs. This prevents the nylon monofilaments from being pulled out (Figs. 53a - d). The Dennison tagging gun for anchoring spaghetti tags is similar, but it leaves the T-bar inside the fish.

Large fish can be tagged without removing them from the water by attaching the tagging needles to long handles to form miniature "harpoons". Mather (1963) illustrates three kinds of dart tag designed for use with this equipment (Figs. 54 - 56).

3.2.5 Internal tags

Internal tags may be inserted subcutaneously or into the body cavity.

Subcutaneous

Le Cren (1954) used a flat subcutaneous tag of monel metal. The ends are cut round to remove sharp corners. "For inserting the tag a finely pointed sharp scalpel is required. A small vertical slit as long as the width of the tag is made in the skin and the skin is lifted and separated from the flesh beneath for a few mm from the slit with the point of the scalpel. The tag is then inserted and pushed between the skin and the underlying muscles with the fingernail. A final push with the scalpel point slides the end of the tag clear of the slit so that it is completely hidden under the skin." Le Cren notes that right handed people find it convenient to insert the tag forward on the left hand side or backward on the right hand side of the fish.

Allen (1963a) notes that for eels, external tags are easily detached but that subcutaneous tags can be used with considerable success. He used a subcutaneous metal tag and employed a miniature "mine detector" for detecting them on recaptured fish.

Andersen and Bagge (1963) inserted tags under the skin and into a lymphatic duct in plaice. In some instances they added a tattoo on the blind side of the plaice to show which individuals had been tagged.

Isaksson and Bergman (1977) described the use of coded wire tags for marking salmon smolts. In these experiments the tags were injected through the snouts and for subsequent recognition the adipose fin was also removed. These fish were subsequently recaptured in a salmon trap and the tags were excised using a cork borer. Fig. 57 shows the applicator used for this kind of tag.

Body cavity

Tags may also be located internally within the body cavity of a fish.

Celluloid tags have been used but the most effective method has been to use magnetic tags which can be detected automatically with the use of appropriate equipment when the fish are recaptured. These tags have been particularly widely used for herring and other fish used in the production of fish meal. In these fisheries most recoveries are obtained from magnets in the factories, usually at a fairly late stage in the reduction process.

Templeman and Pitt (1963) show how an internal tag may be inserted into the body cavity of a cod using a scalpel. They note that this is done by making a small slit parallel to the long axis of the body and pushing the tag firmly through it into the body cavity.

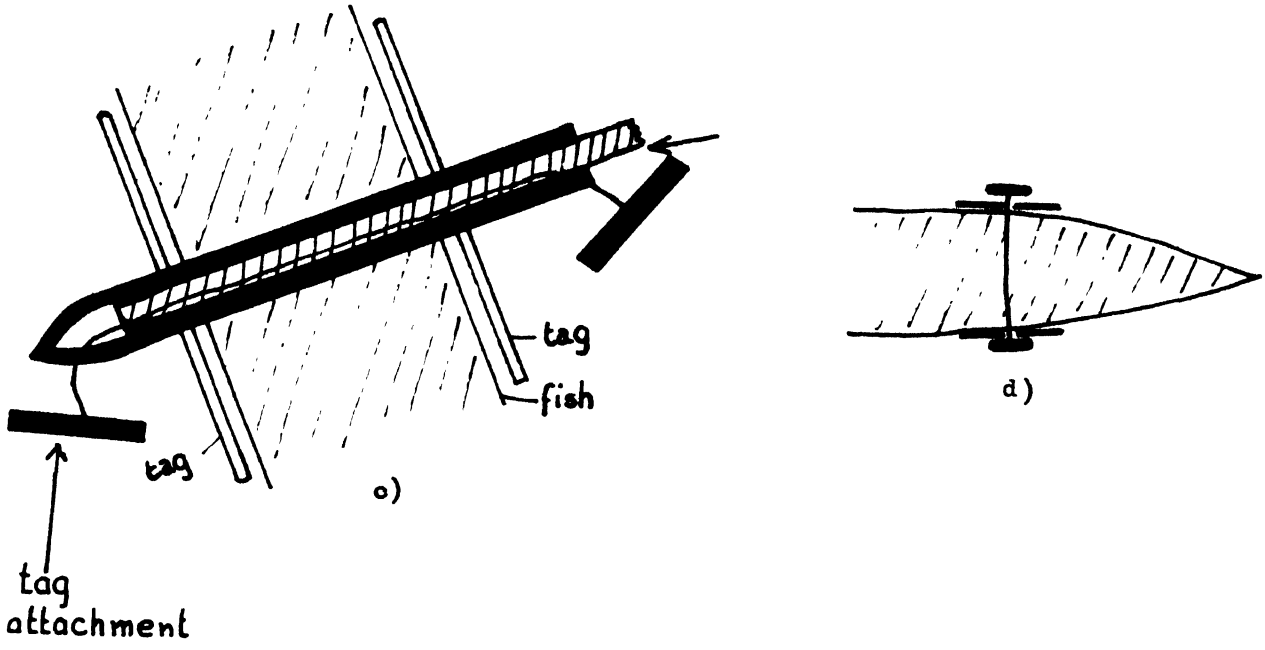


Fig. 53 (contd.) - c) Enlargement of needle with tag attachment in position through fish, and with needle ready to be withdrawn

d) Tag attachment and Petersen discs on fish

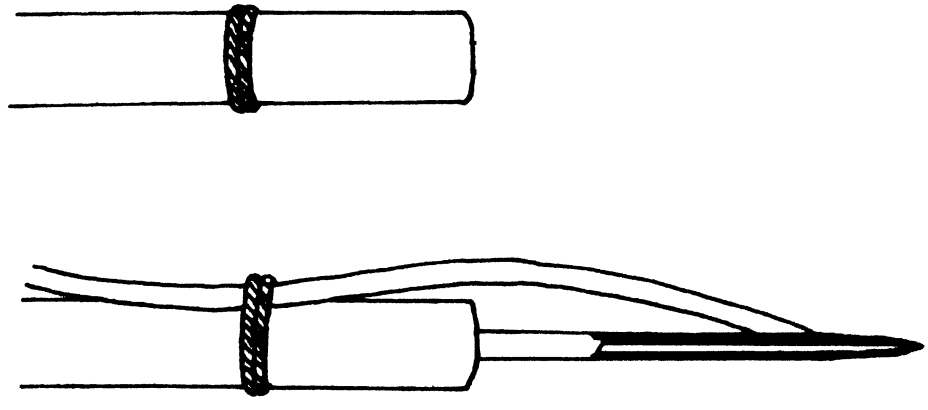
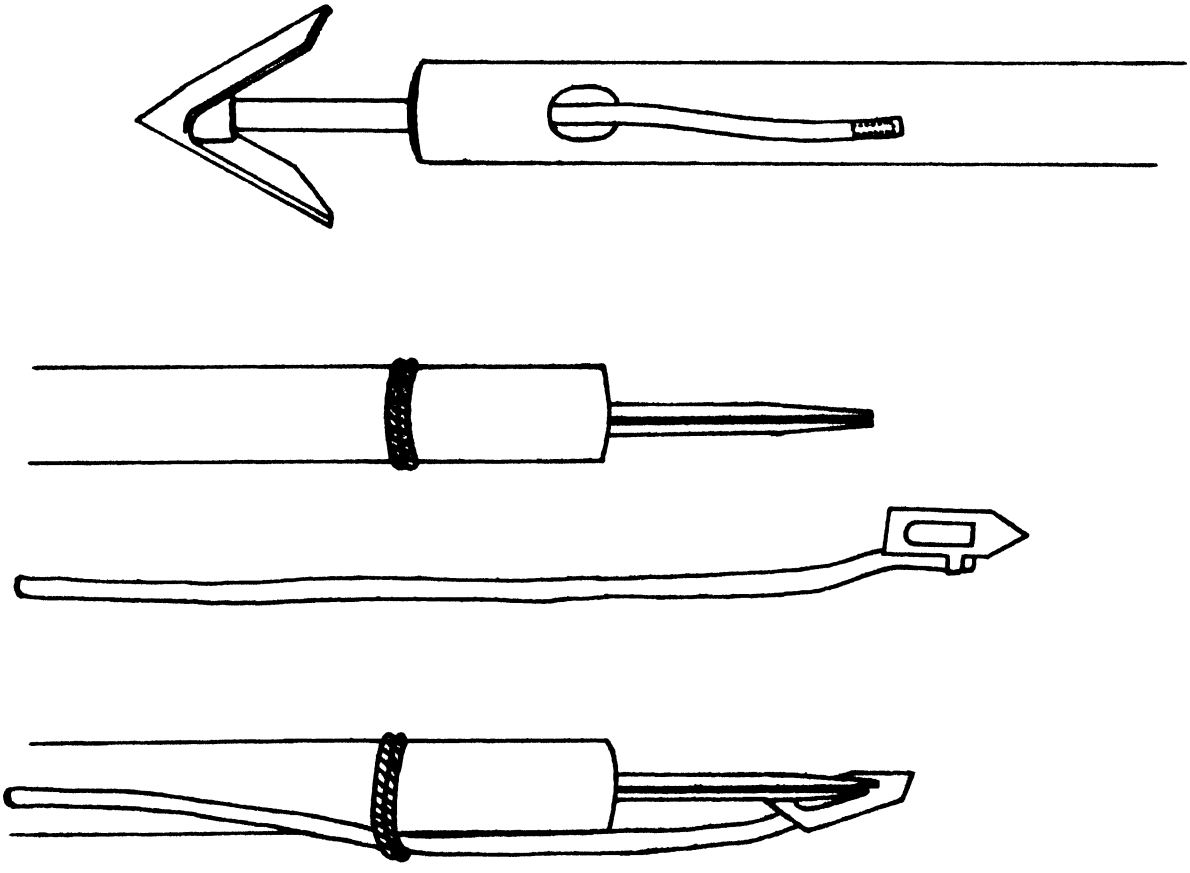


Fig. 54 - 'Harpoon' applicators for attaching various dart tags to tuna without removing them from the water (Redrawn from Mather, 1963)



Figs. 55 and 56 - 'Harpoon' applicators for attaching various dart tags to tuna without removing them from the water (Redrawn from Mather, 1963)

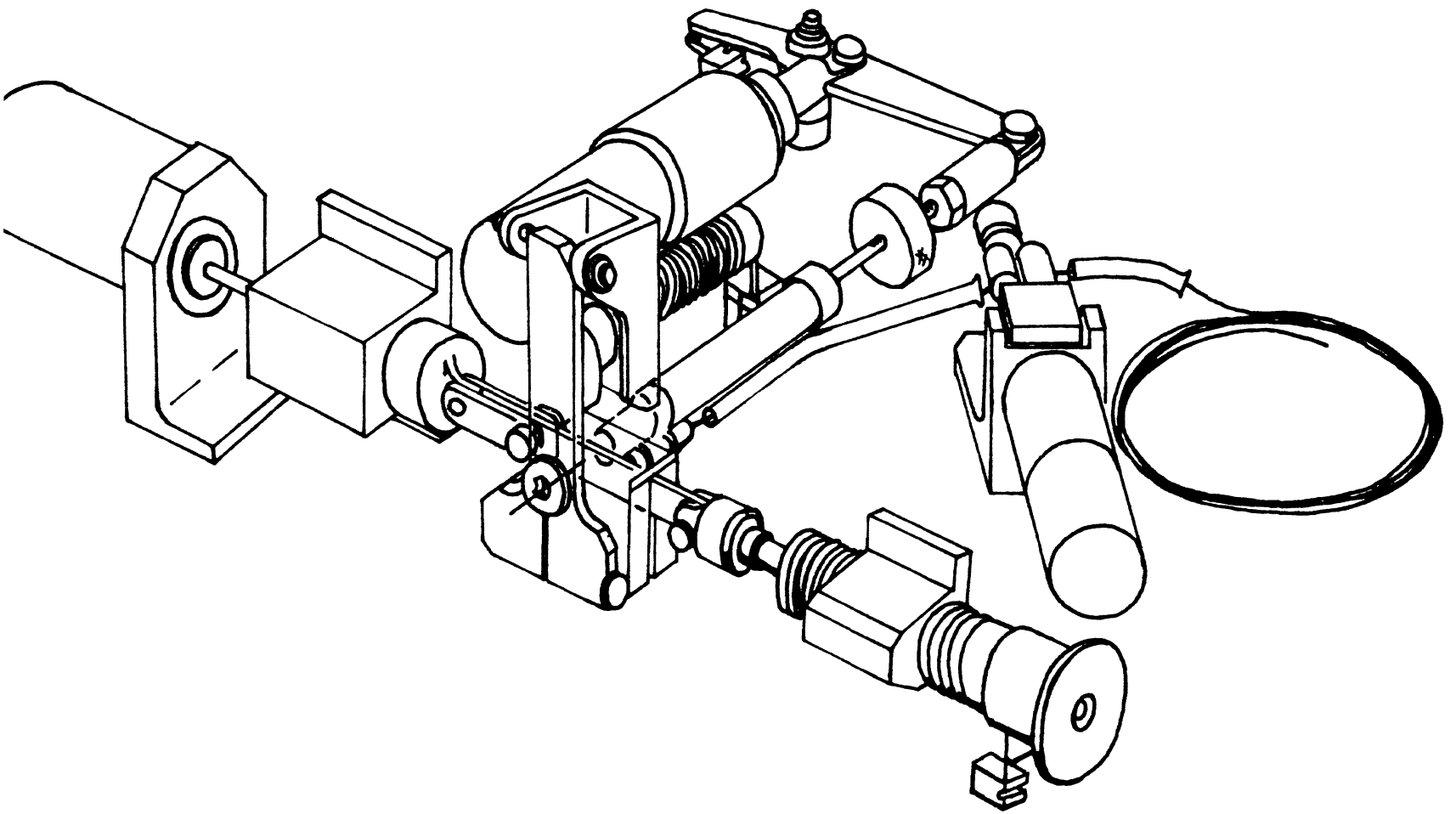


Fig. 57 - Applicator used for coded wire tags
(Redrawn from West and Chew, 1968)

The speed at which fish can be tagged internally was greatly increased by the tagging gun described by Fridriksson and Aasen (1952). The gun takes a magazine of 50 internal tags on one side of the barrel, and by pulling the trigger the scalpel moves forward to make an incision in the body cavity and at the same time a rod moves forward pushing one of the tags into the hole made by the scalpel (Fig. 58).

3.2.6 Combination tags

The term "combination tag" usually refers to a combined anchor and roll tag. The anchor is normally inserted into the body cavity using a scalpel and forceps, as described above. Hence part of the tag is visible from outside and it is not necessary for the internal part to be of magnetic material. Figs. 59a-i show the attachment to a plaice of a roll tag in which the anchor plate is attached subcutaneously. "The tag is attached to the fish in the following way. In the middle of the dorsal part of the blind side, just inside the radials, where a lymphatic duct is running, an incision is made in the skin (about 5 mm) at right angles to the longitudinal axis of the fish. The nylon loop is put through the eye of the needle, and the needle is pushed about 30 mm in under the skin toward the tail, whereupon the needle is pushed obliquely through the musculature and out through the pigmented side. The nylon loop is pulled through, and the anchor plate is inserted under the skin on the blind side so that it is placed as shown in Fig. 59e. Now the needle is pushed through the roll, and the nylon loop is pulled through this. The needle is taken out of the loop, to which a locking bead is fastened by a reef knot." (Andersen and Bagge, 1963). Figs. 60a - f show the attachment of a combination tag with the anchor plate in the body cavity.

3.2.7 Making up a nylon attachment

Figs. 61a - e show how to attach a nylon thread to a plastic flag tag.

3.3 Attachment positions

3.3.1 General principles

Commonly used attachment positions for external tags are the jaw, the operculum, the dorsal musculature and the caudal region (Fig. 62). Alverson and Chenoweth (1951) examined the behaviour of fish tags on albacore secured in a water tunnel. They concluded that any tag attached to the head or anterior region of the fish received the maximum force from the water. Tags located on the caudal region would receive the greatest action from the lateral vibration of the tail. For these reasons a dorsal position is probably best for external tags.

3.3.2 Dorsal

Aslanova (1963) notes that it is most important when attaching tags dorsally not to place them too close to the fin lest they prevent its normal vibration. On the other hand, if the attachment is made too far below a fin the wound is not likely to heal rapidly.

Williams (1963) notes that, where there is more than one dorsal fin, a position between the first and second dorsal fin is most commonly used. He considers that there is no evidence that the position in front of the first dorsal fin is necessarily more suitable than any other dorsal position. It should be noted that however a tag is placed in relation to the dorsal fin, the point of attachment should always be above the lateral line.

Calhoun (1953) illustrates four kinds of tag attached dorsally on striped bass (Figs. 63a - d). For flatfish, Petersen discs have been attached below the dorsal fins (Fig. 64).

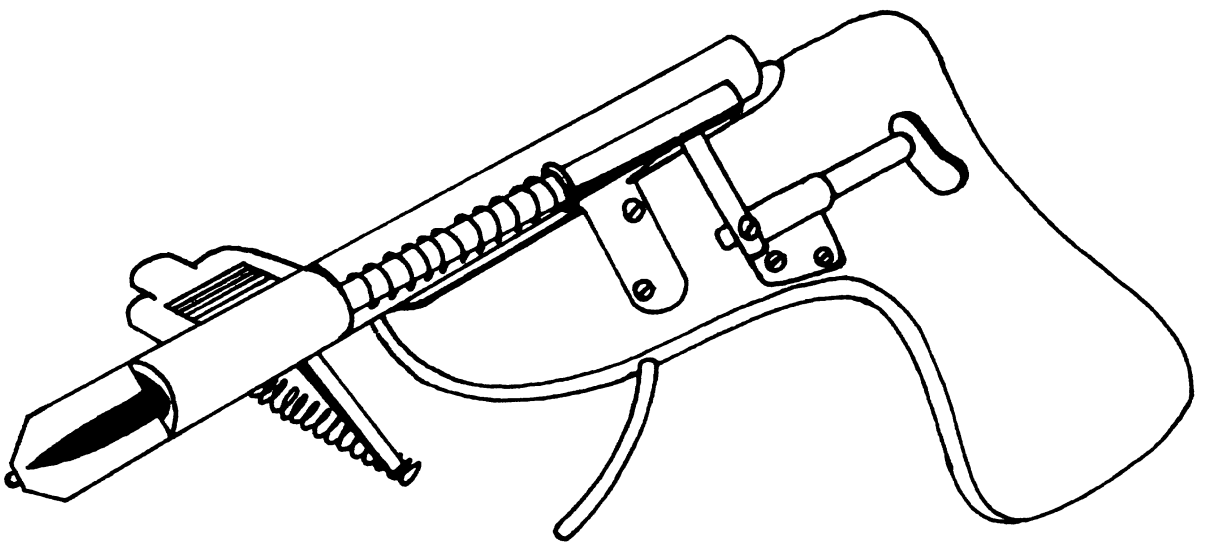


Fig. 58 - Tagging gun for inserting internal tags into the body cavity
(Redrawn from Jakobsson, 1970)

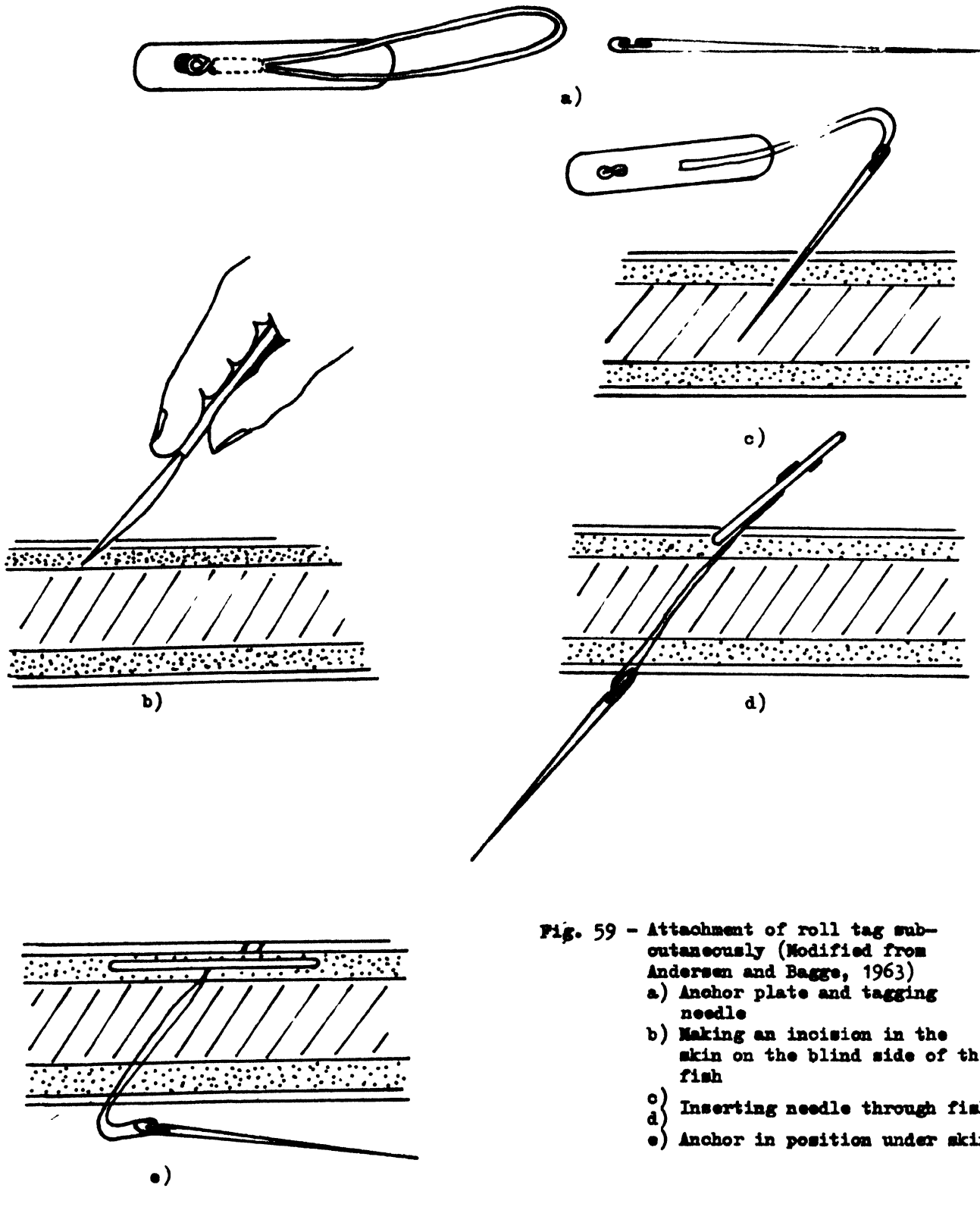


Fig. 59 - Attachment of roll tag subcutaneously (Modified from Andersen and Bagge, 1963)
a) Anchor plate and tagging needle
b) Making an incision in the skin on the blind side of the fish
c) d) Inserting needle through fish
e) Anchor in position under skin

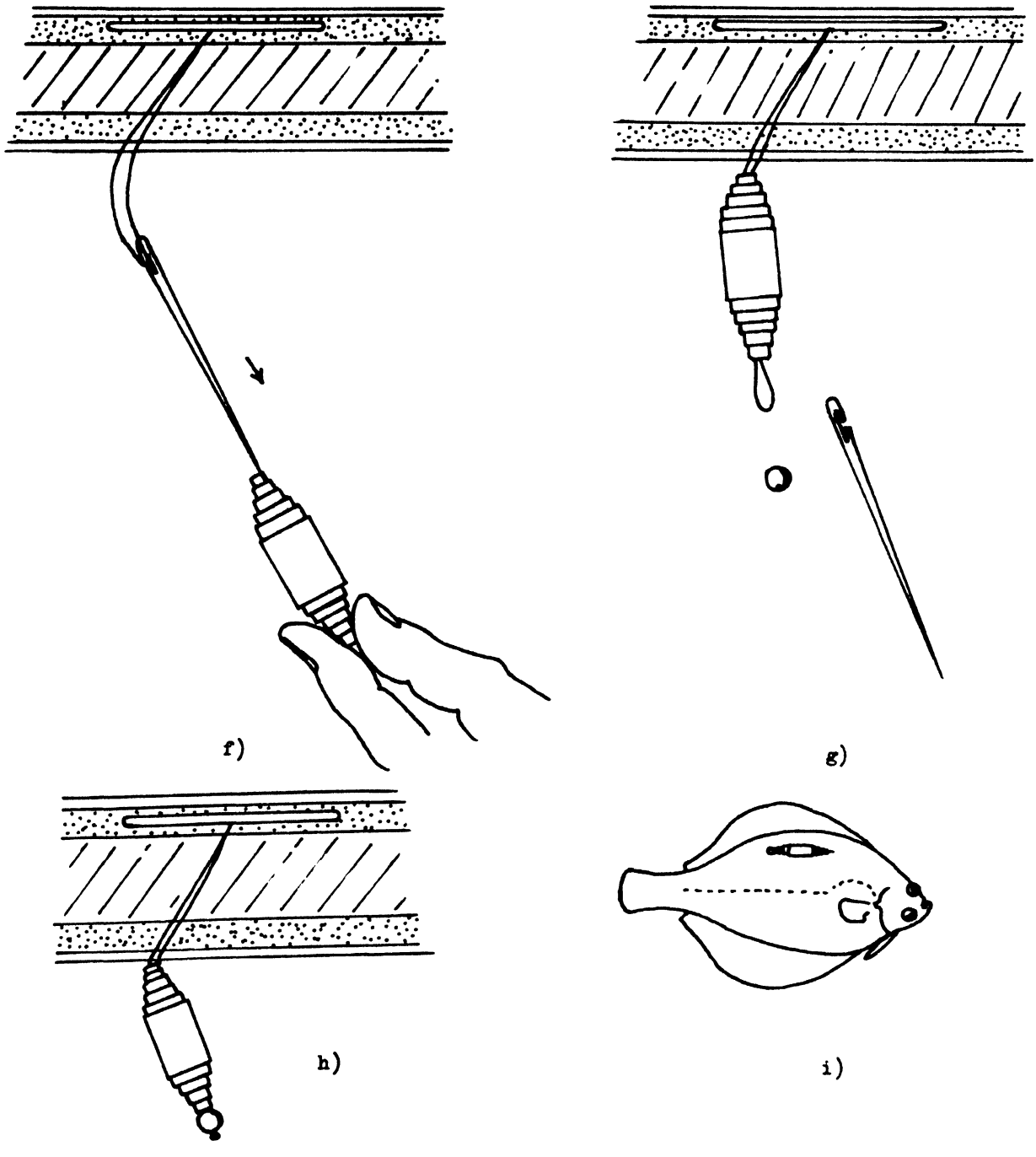


Fig. 59 (contd.)
f) Threading the 'roll' onto the needle
g) Removing needle and fastening locking bead into position
h)
i) The tag in position

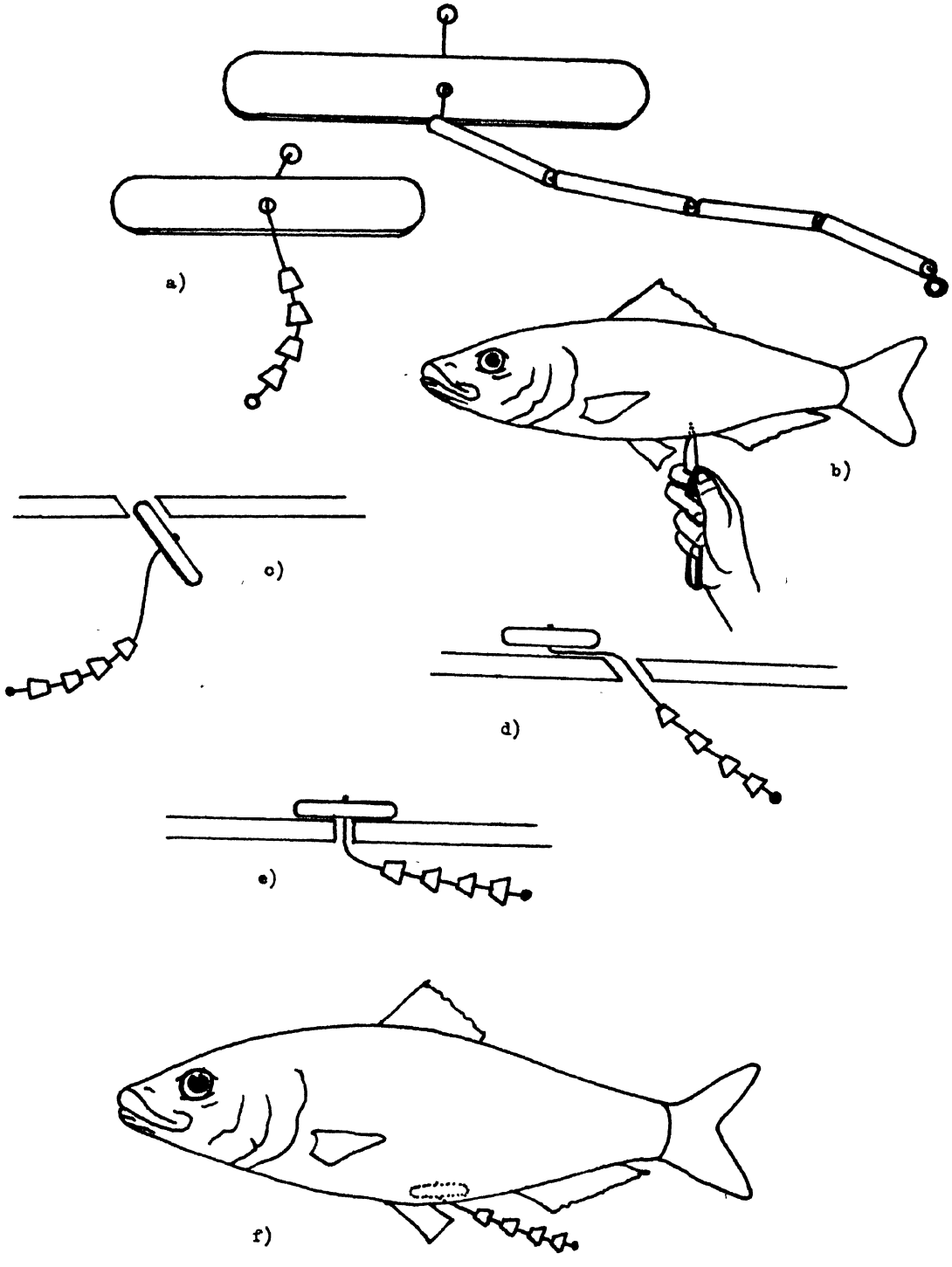


Fig. 60 - Attaching a combination tag internally to a roundfish (Redrawn from Åkyüz, 1965)
a) 2 combination tags with alternative dangling portion
b) Making an incision in the body cavity
c) - e) Inserting the anchor plate into the body cavity
f) The tag in position

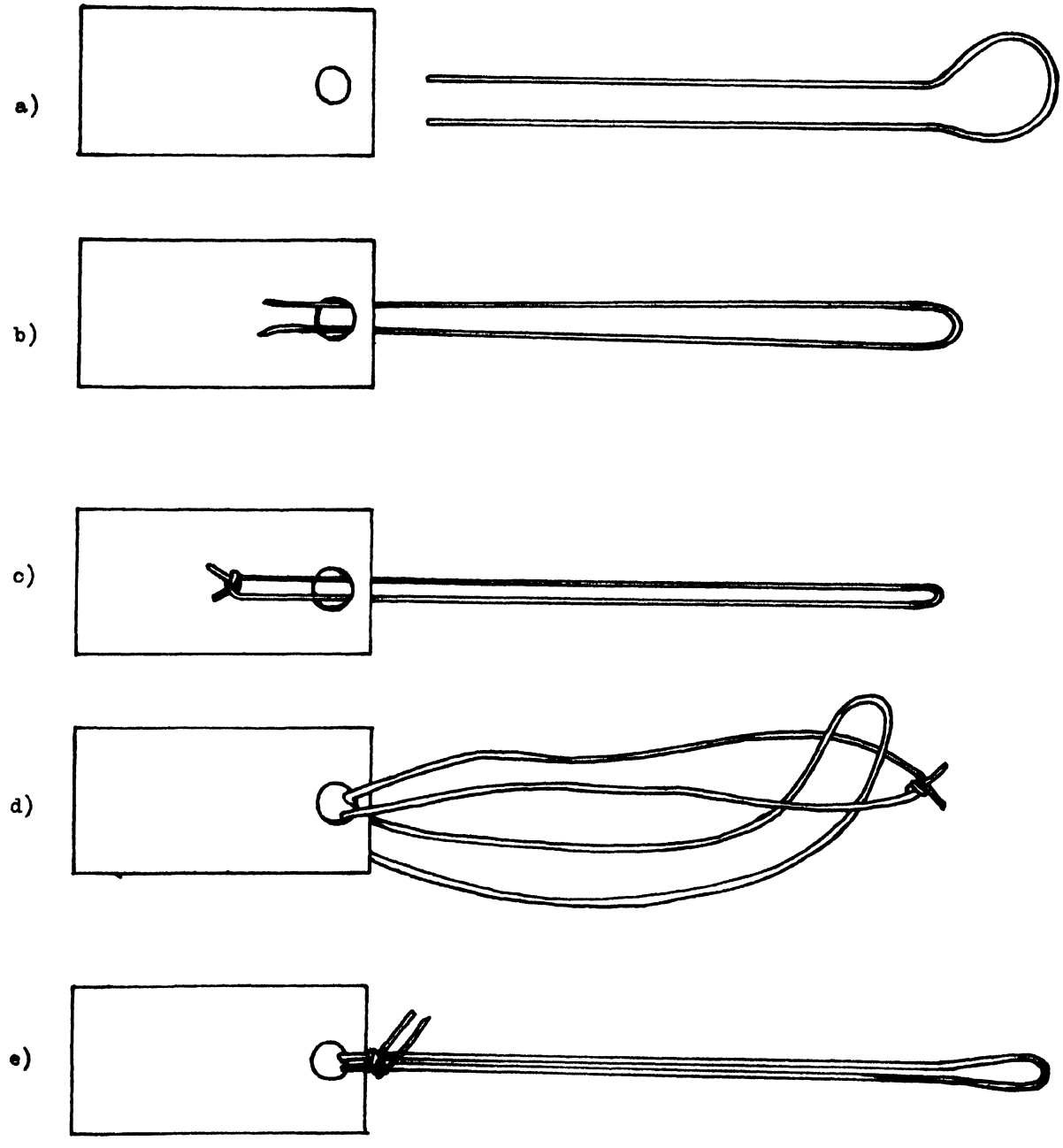


Fig. 61 - Making a nylon loop and attaching it to a flag tag
a) b) The 2 ends of the loop are passed through a hole in the tag
c) The 2 ends are knotted
d) The loop at one end is passed through the loop at the other
e) The thread is pulled tight

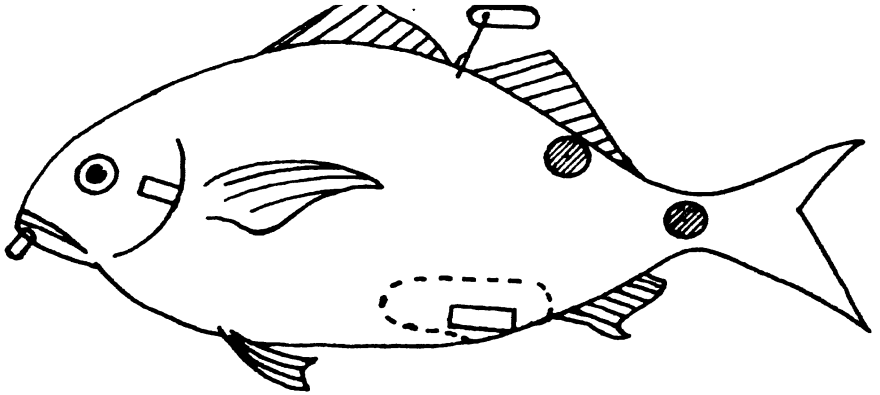
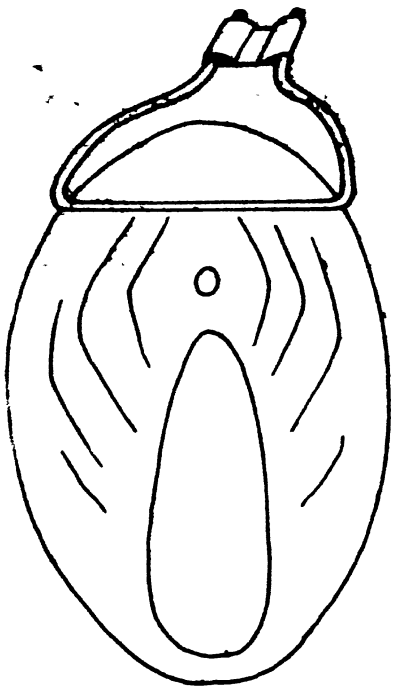
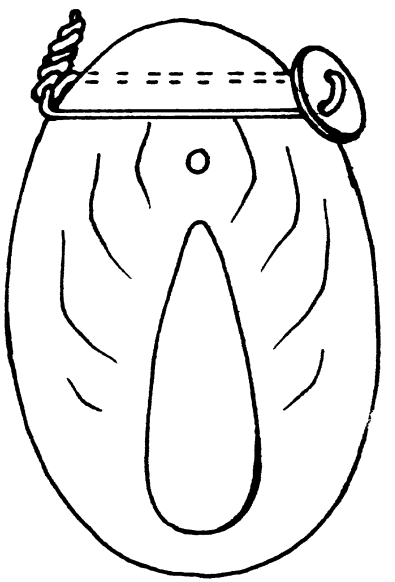


Fig. 62 - Showing the principal attachment positions (Modified from Thomson, 1963)

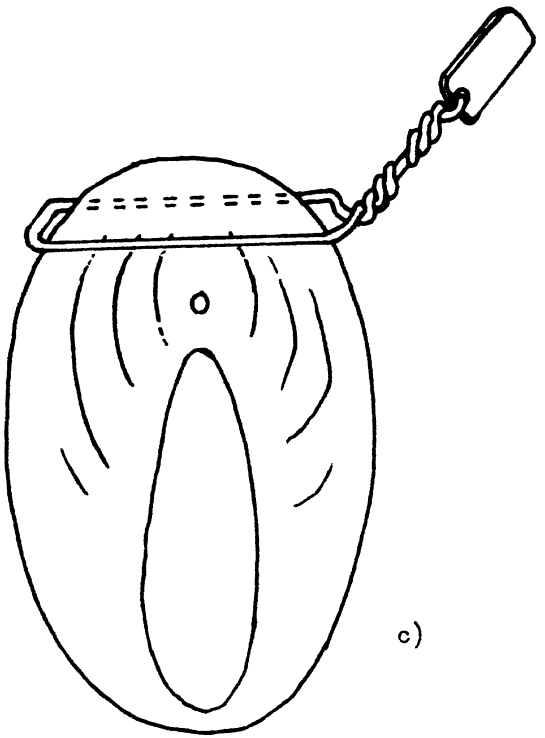


a)

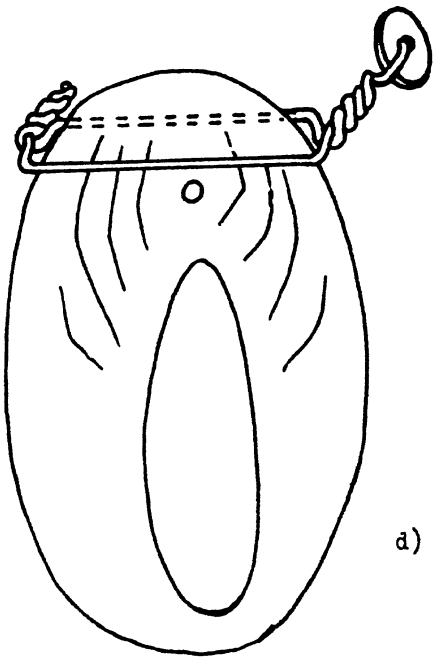


b)

Fig. 63a - d - Some examples of tags attached dorsally (Redrawn from Calhoun, 1953)



c)



d)

Fig. 63a - d (contd.)

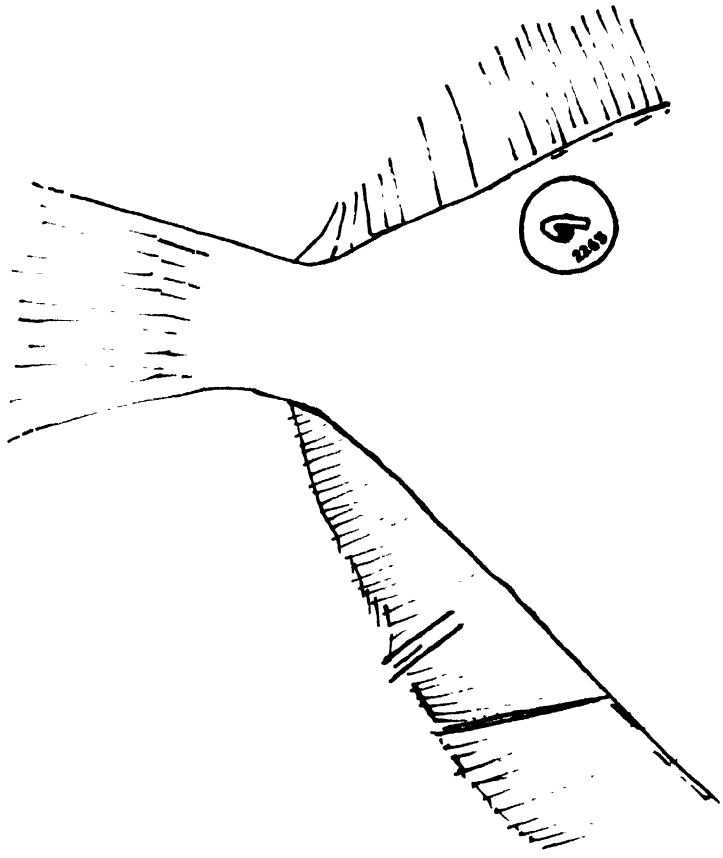


Fig. 64 - Petersen tag attached dorsally on a plaice

Yamashita and Waldron (1959), referring to the tagging of tuna with dart tags (Section 3.2.2), emphasize that the tag should be inserted so that the barb lodges against a neural spine. To ensure this, the tag should be inserted as shown in Fig. 65a and not as shown in Fig. 65b.

3.3.3 Opercular and jaw

Petersen tags are sometimes attached to the operculum, one of the discs being located inside and the other outside the cheek (Fig. 66). Dangling tags may be attached to the operculum by a wire with or without the use of a hollow needle (Fig. 67). Strap tags are particularly suitable for attachment to the operculum or to the jaw (Fig. 68).

3.3.4 Caudal peduncle

Calhoun (1953) attached Petersen disc tags to the caudal peduncle of striped bass. He noted that too few tests were done to say how satisfactory this was (Fig. 69).

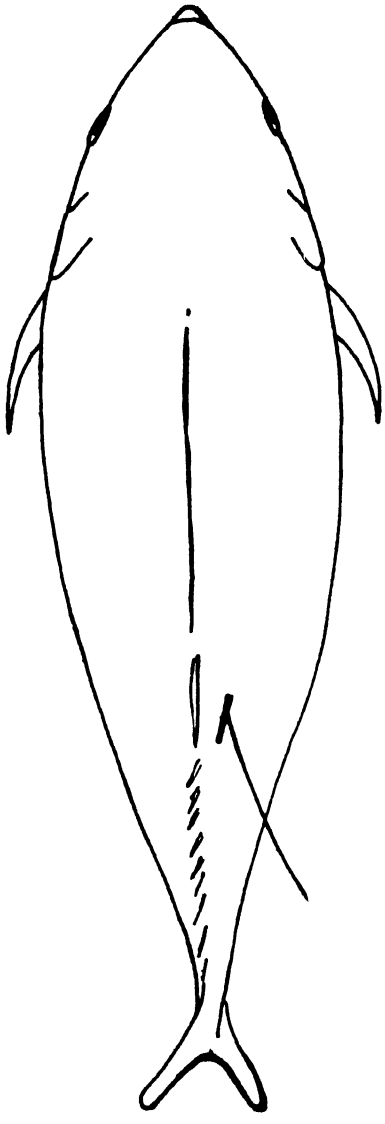


Fig. 65a - Correct alignment of barb of dart tag on tuna

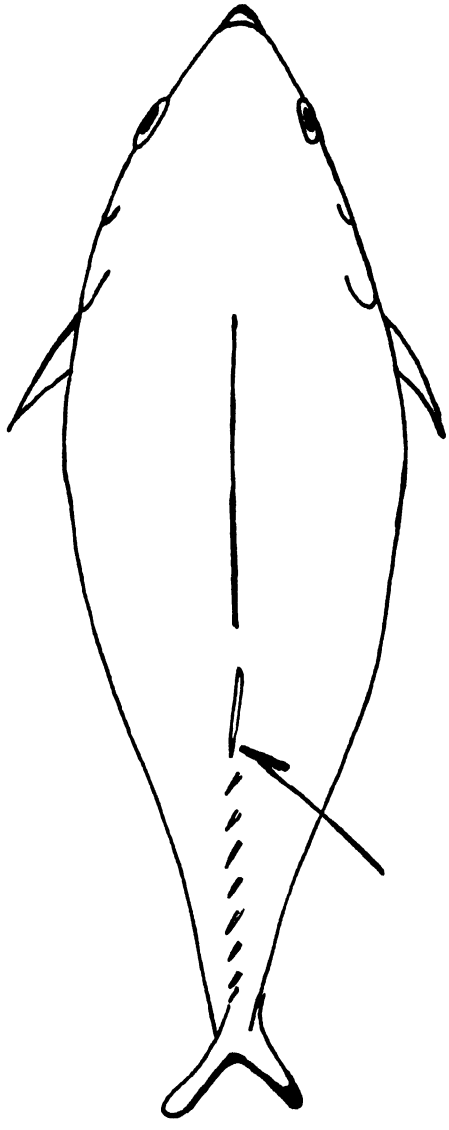


Fig. 65 b - Incorrect alignment of barb

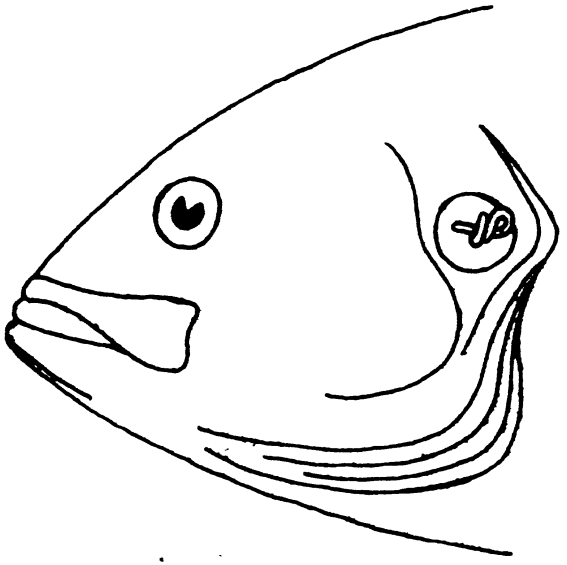


Fig. 66 - Petersen disc on operculum

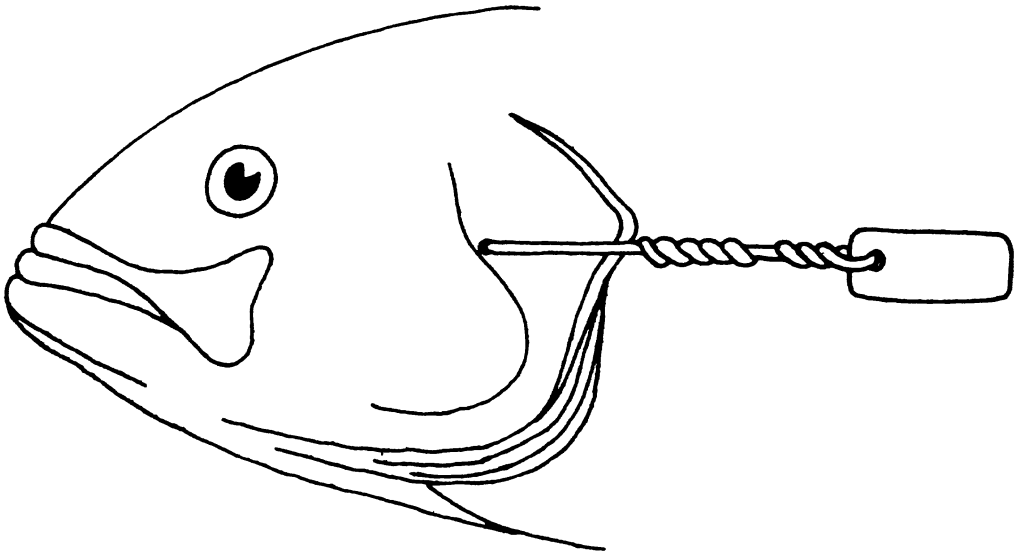


Fig. 67 - Archer tag on operculum

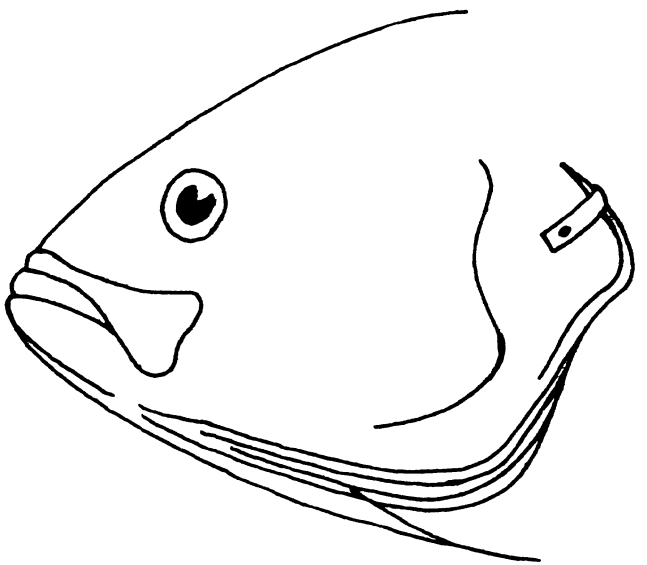


Fig. 68 - Strap tag on operculum
(Figs. 66-68 redrawn from Calhoun, 1953)

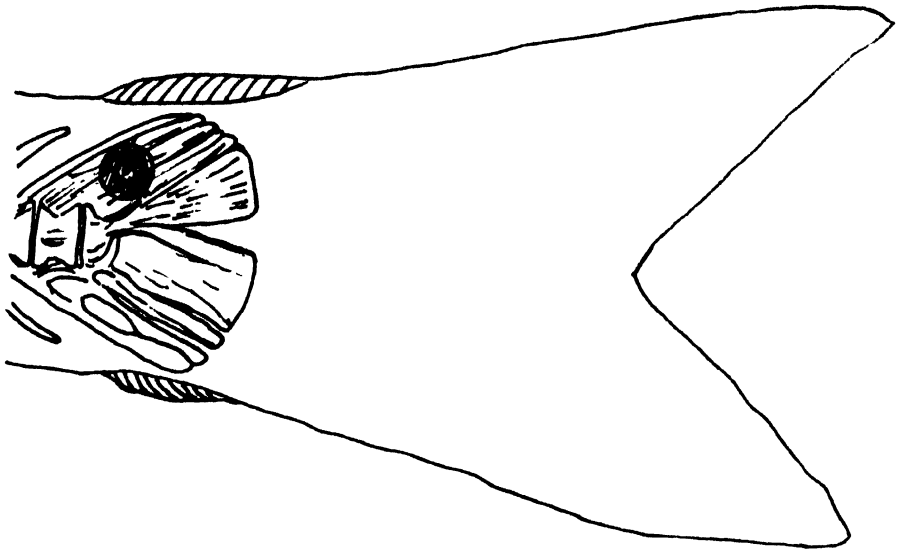


Fig. 69 - Petersen disc attached to caudal peduncle
(Redrawn from Calhoun, 1953)

Petersen discs, when tightly attached in the dorsal region, will naturally obstruct growth and cause lesions or deformities if the fish remains at liberty for a considerable time. These problems can be largely avoided by putting a small spacer bar on the pin inside each tag.

3.3.5 Subcutaneous and internal

A subcutaneous tag may be inserted under the skin on any part of the body. In the case of plaice they have been introduced into the lymphatic duct (Anderson and Bagge, 1963). Coded wire tags may also be inserted under the skin of any part of the body. Isaksson and Bergman (1977) injected them into the snouts of smolts.

Internal tags other than subcutaneous tags are normally introduced into the body cavity.

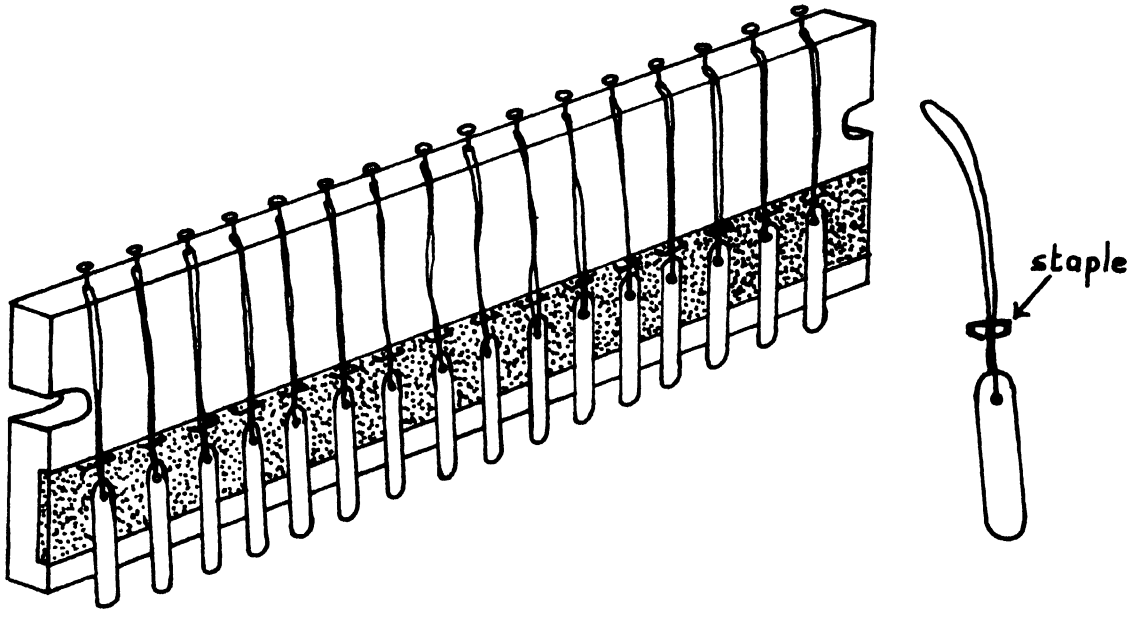
3.4 Tag holders

A considerable amount of time can be saved if tags can be arranged in serial order in a special holder.

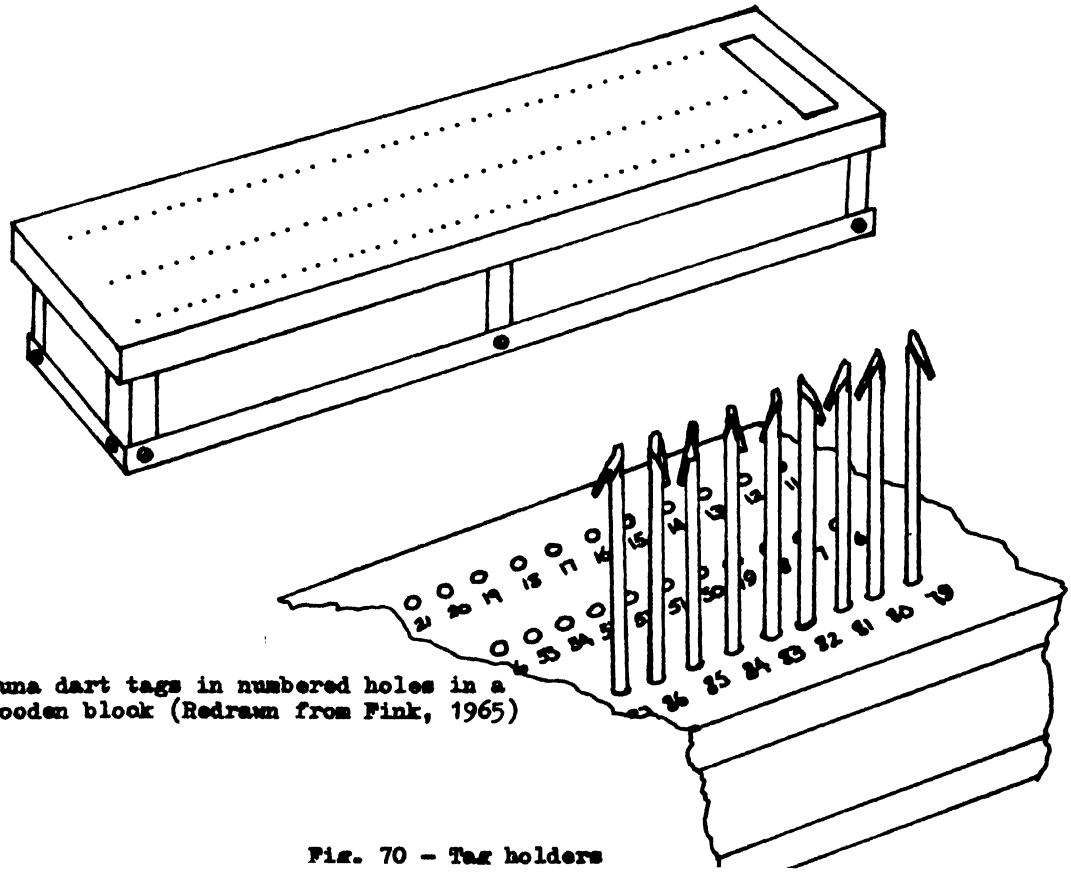
Collyer and Young (1953) suggest that, when using Petersen tags, the pins should be fitted into one of the discs prior to the tagging operation. Sufficient tags and pins should be mounted in advance to speed up operations.

Hislop (1969) describes a tag holding board suitable for plastic flag tags with nylon threads. The tags are arranged in serial order as shown in Fig. 70a. Hislop was concerned with underwater tagging and for this purpose each tag was stapled lightly onto a block of plasticine.

Bayliff (1973), using dart tags for tunas, noted that prior to use the tags are loaded into needles and put in groups of 100 in serially numbered holes in wooden blocks. These blocks are 9 x 9 x 30 cm and are kept in groups of 3 in wooden carriers for ease and safety when transporting. An appropriate number of magazines can be prepared in advance for each day's tagging if so required. A similar arrangement is described by Fink (1965) (Fig. 70b).



a) Flag tags with nylon attachments pinned onto a board. The flags are held in place by staples embedded in plasticine so that they can be easily freed (Redrawn from Hislop, 1969)



b) Tuna dart tags in numbered holes in a wooden block (Redrawn from Fink, 1965)

Fig. 70 - Tag holders

3.5 Dimensions of tags, wires and tagging needles

The appropriate size of tag, wire or tagging needle depends to some extent on the size of the fish to be tagged. Some examples from the literature are referred to below.

3.5.1 Dimensions of tags

Templeman and Pitt (1963) tried various sizes of tag on cod 50 cm or more in length. Good return rates were obtained with 51 mm-long red flag tags of laminated cellulose nitrate, 9.5 mm wide and 0.9 mm thick attached by nickel wire to the pre-operculum, and with bright orange internal tags of laminated vinylite 76 and 102 mm-long, 9.5 mm wide and 0.9 mm thick. Sandeman and Rees (1963) tagged redfish with 20 x 5 mm yellow vinylite laminated plastic tags attached dorsally with wire. Le Cren (1954) used a tag of monel metal 15 x 4 mm, and 0.254 mm thick for subcutaneous application.

3.5.2 Dimensions of wires

Allen (1963) attached tags to trout 12 or more cm in length with silver wire 0.45 mm in diameter. Templeman attached tags to cod 50 cm or more in length with nickel wire with diameters ranging from 0.51 to 0.02 mm. He also used stainless steel wire with diameters ranging from 0.38 to 0.81 mm. For attaching the Lea hydrostatic tag he used stainless steel wire 0.6 mm in diameter. Sandeman and Rees (1963) attached flat plastic tags to redfish with stainless steel wire 0.64 mm diameter. They also used 0.81 mm diameter stainless steel wire to attach Petersen disc tags.

3.5.3 Diameters of tagging needles

For tagging tuna, Bayliff (1973) used stainless steel needles of two sizes:

3.810 mm inside diameter with wall thickness 0.381 mm and

3.429 mm inside diameter with wall thickness 0.381 mm.

3.6 Comparison of tags and attachments

A number of experimental results have been reported comparing the durability and return rates of various tag materials and attachments.

3.6.1 Comparisons of different tag types

Hartt (1963), working with salmon, compared disc tags and spaghetti tags. He found that the disc tags yielded almost double the return rate of the spaghetti tags and thought that this was due to the better visibility of the discs. He also compared different sizes of disc and found that 18 mm diameter discs yielded a better return rate than 12 mm diameter discs.

McCracken (1963) compared Petersen disc type tags with Lea hydrostatic tags on cod. He found that the Petersen tags produced the highest percentage of returns (60%) compared with only 32% for the Lea hydrostatic tag. Monel metal strap tags yielded only 27% returns.

Williams (1963) working with soles and plaice found that Petersen discs gave better returns than arrow or flag tags.

McDermott and Livingstone (1963) found that spaghetti tags gave a higher rate of return than Petersen disc tags when passed through the dorsal musculature of haddock. Marr (1963) working with skipjack tuna reports that return rates were increased approximately tenfold when the change was made from spaghetti tags to dart tags. He considered that this was a reflection of increased survival rates resulting from decreased handling time.

Jensen (1963) considered that no one tag was vastly superior for haddock tagging. "However the spaghetti tag is recommended over others because it is easily attached, does not irritate the fish at the point of attachment, cannot be overgrown with tissue, is probably not easily shed and can remain on the fish for at least 4 years."

Rounsefell (1942) compared Petersen discs, bachelor buttons and anchor tags on haddock. The anchor gave the poorest returns because of the early loss of the dangling portion. The Petersen disc gave the highest rate of return initially but overall the bachelor button appeared most efficient.

3.6.2 Comparisons of tags of different colours

Neilson (1963) compared various tags on cod, char and salmon. Experiments with cod gave the following results in decreasing order of return rate: red plastic tags attached with steel wires; yellow plastic tags attached with steel wire; Lea tags; red plastic tags with terylene attachment; yellow plastic tags with terylene attachments and Petersen tags. The Petersen tags were attached to the operculum but all the others were attached dorsally. Experiments with char and salmon gave the same order of results (Petersen tags not used). In general he concluded that a red colour gave a higher rate of return than yellow. Also tags attached with steel wire gave a higher percentage rate of return than tags attached with terylene.

Lawler and Smith (1963) compared transparent (colourless) with opaque yellow tags on small perch less than 15 cm in length. They found that the return rate of the opaque yellow tags was significantly smaller than that of the clear transparent ones. They concluded that this was due to a higher predation rate by pike on small fish with opaque yellow tags.

Ancellin (1963) working with herring claimed good results with Lea tags and concluded that this was due to their conspicuous yellow and blue colours. Parrish and McPherson (1955) working with herring concluded that tags having yellow or red gave much better results than tags of other colours. Templeman (1963) working with cod considered that orange external tags gave slightly better returns than yellow or red tags of the same size.

3.6.3 Effect of anti-fouling treatment

Williams (1963) compared untreated plastic tags with plastic flag tags incorporating an anti-fouling compound (5% of phenyl mercury acetate was added to the PVC before the sheet was extruded). For periods of liberation of up to 100 days there was no significant difference in the percentage returns by either type of tag. For longer periods, however, the anti-fouling tag gave a higher return rate. Williams notes that marine organisms tend to attach themselves to the surface of the tag and to the bridle in the untreated tags (Figs.71 and 72).

3.7 Other methods of marking

3.7.1 Fin clipping

An excellent account of fin clipping and the conditions for subsequent regeneration of the fins are given by Stuart (1958). In the case of the pelvic fins, providing all fin rays are removed right down to their point of attachment to the pelvic bone no regeneration of the fin occurs. In this situation the site of the fin becomes covered by scar tissue (Fig. 73).

A cut near the base of the fin leaving the base of the fin rays intact can lead to almost complete regeneration of the fin with just a small amount of distortion at the point where the cut is made (Fig. 74).

A cut which removes only some of the fin rays down to the base leads to complete regeneration of those fin rays that were not completely eliminated. This can lead to considerable distortion of the regenerated fin (Figs. 75a - c).

Fig. 71 - Growth of fouling organisms on untreated plastic flag tag (Redrawn from Williams, 1963)

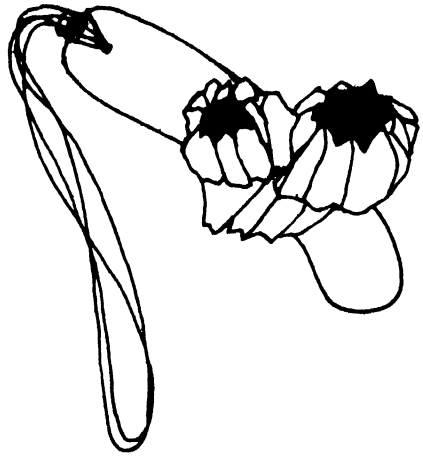


Fig. 72 - Barnacles growing on plastic flag tag (observed by author on tag attached to Faroe haddock after more than 1 year at liberty)

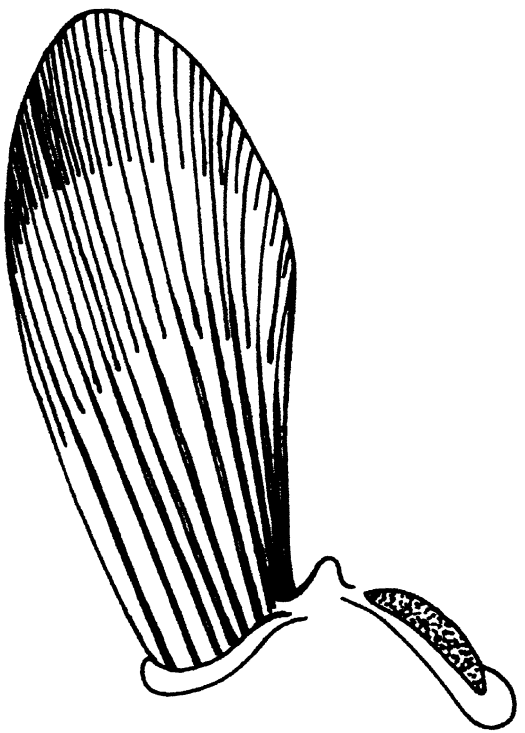


Fig. 73 – Fin rays removed down to point of attachment to pelvic bone – no regeneration
(Redrawn from Stuart, 1958)

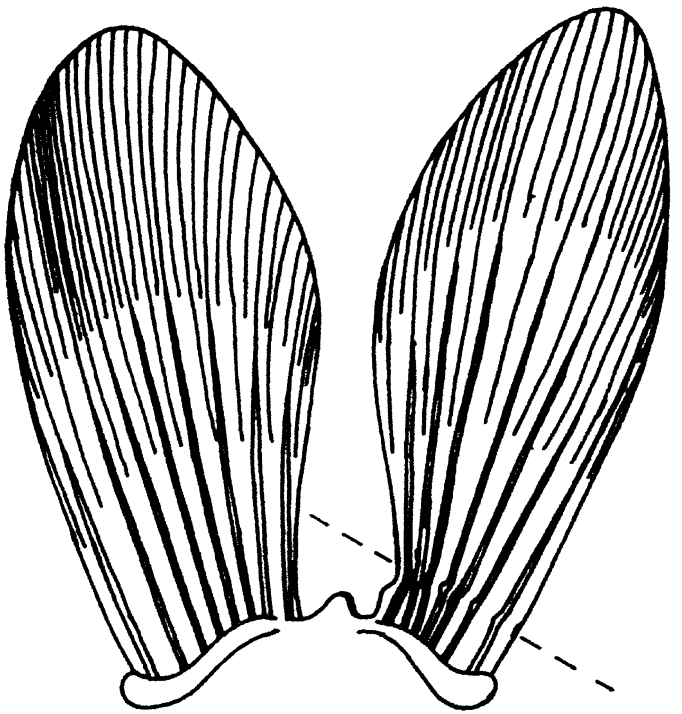


Fig. 74 – Fins cut near base of fin can lead to almost complete regeneration – just a small amount of distortion
(Redrawn from Stuart, 1958)

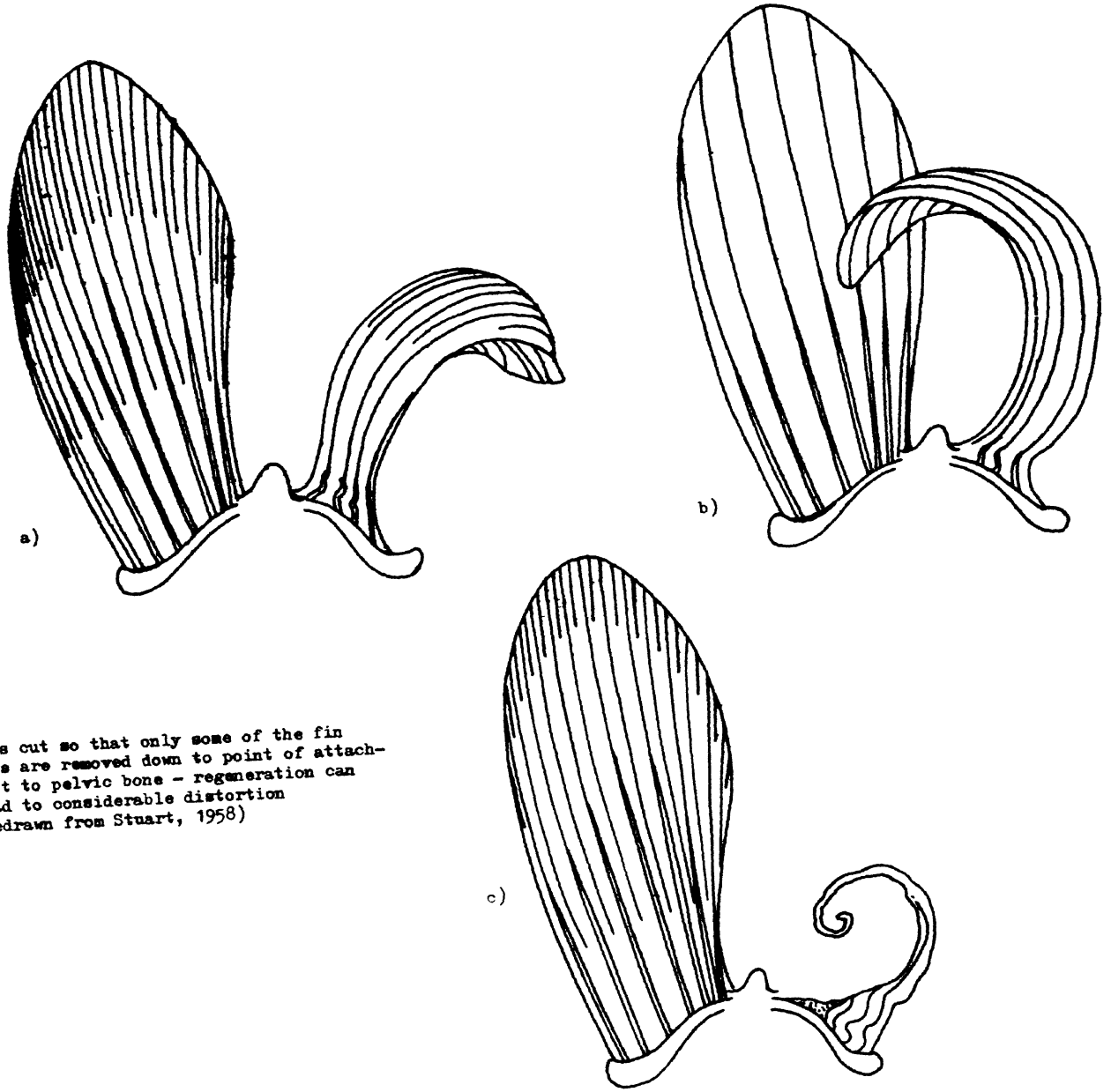


Fig. 75a - c - Fins cut so that only some of the fin rays are removed down to point of attachment to pelvic bone - regeneration can lead to considerable distortion (Redrawn from Stuart, 1958)

Repeated marking of the same individuals can be done by making use of the regenerative powers of the fins. For example, Fig. 76a shows a fish that is cut first along the line a-a', and then when recaptured after regeneration of the fin along the line b-b'. Fig. 76b shows the effect of making 3 cuts on the same fin.

Clipping of the dorsal or caudal fins leads to regeneration but with some distortion (Figs. 77a, b and 78a, b).

The punching of holes or creating of notches in fins leads eventually to complete regeneration (Figs. 79a - f). In the case of the adipose fin regeneration does not occur but it may be difficult to tell that a fin has been clipped (Figs. 80a, b) unless the fin is completely eliminated (Figs. 81a, b).

Rinne (1976) describes an experiment in which the spines of Tilapia are clipped. The species studied has 14 to 18 spines in the dorsal fin and 3 in the anal. He used the first 9 dorsal spines coded as units and the 10th to the last as tens, i.e., the 11th spine is designated as 20, the 12th as 30, etc. The anal spines were utilized as 100s. In this way it was possible to code for identifying individual fish (Fig. 82). He noted that in fish greater than 15 cm the mark was permanent although considerable regeneration occurred in younger fish. Van Someren and Whitehead (1959) also describe a fin clipping experiment using Tilapia.

3.7.2 Immersion in stains

Immersion in a dilute solution of biological stain is particularly useful because a minimum of handling is required. However, so far no dye has been found which produces a permanent mark and stained fish may not be recognizable for more than one month. There is also the difficulty that chemical marking leads to loss of individuality. It is only suitable therefore for applying an identical mark to a number of individuals at the same time. For immersion staining the best dyes now available are neutral red, Bismarck brown Y, acridine orange and rhodamine B. Further details are given by Arnold (1966).

3.7.3 Injection of stains

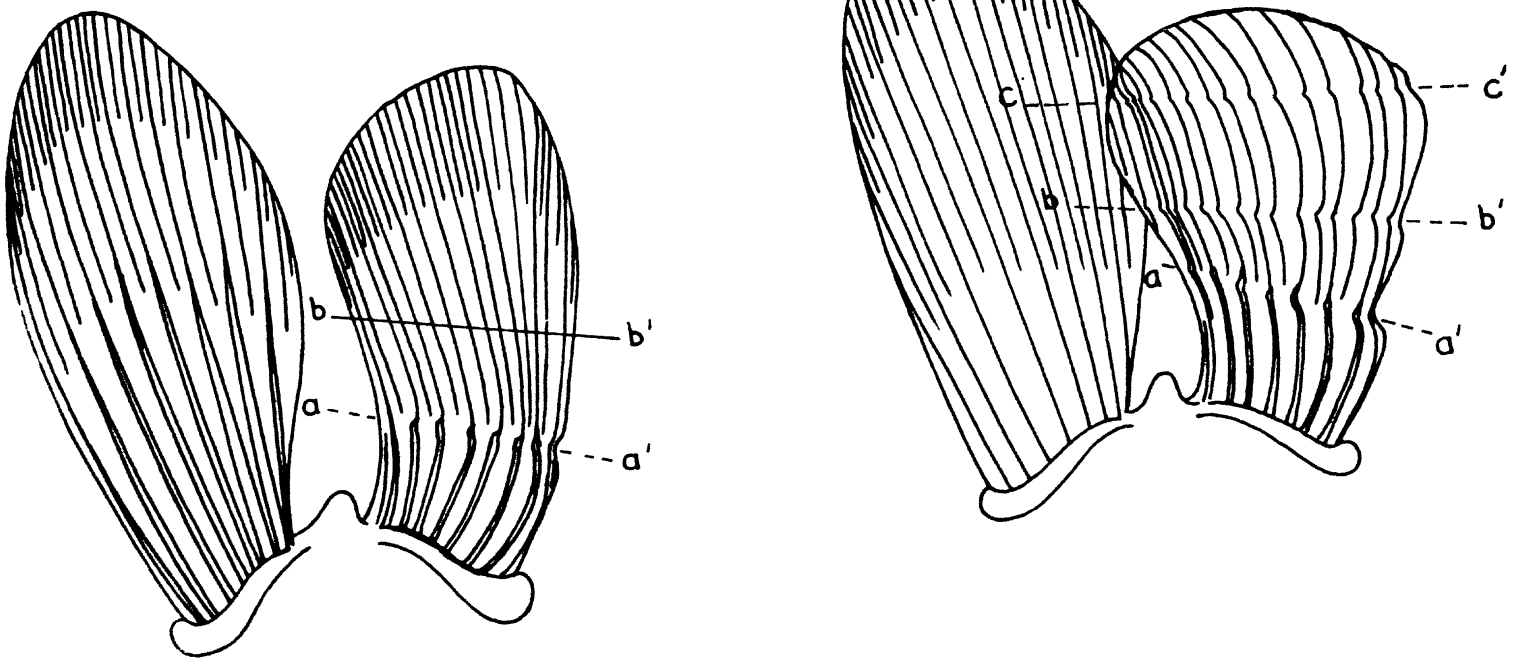
Hart and Pitcher (1969) used a jet inoculator to mark fish. This instrument injects dyes subdermally and the technique provides a long lasting batch mark which is easily and quickly applied and which inflicts minimal damage to the fish. Their inoculator was obtained from dental suppliers.

The dyes recommended or used are National fast blue 8GXM, Durazol blue, Alcian blue and Indian ink. After injection, the fish should be swabbed free of excess dye. Small fish should be dipped in water to avoid damage and to check that a clear mark has been made. In from 5 to 20% of instances, a second marking was required to give a satisfactory result but fish can be marked at rates of up to 30 a minute (Hart and Pitcher, 1969).

Arnold (1966) points out that dyes that diffuse are unsatisfactory for injection purposes and often result in an all-over coloration. Injection of dyes and other substances for the production of spots and lines however is much more promising. According to Arnold, promising materials are Incarbon, cadmium sulphide, chrome green, National fast blue 8GXM, and mercuric sulphide.

3.7.4 Injection of latex

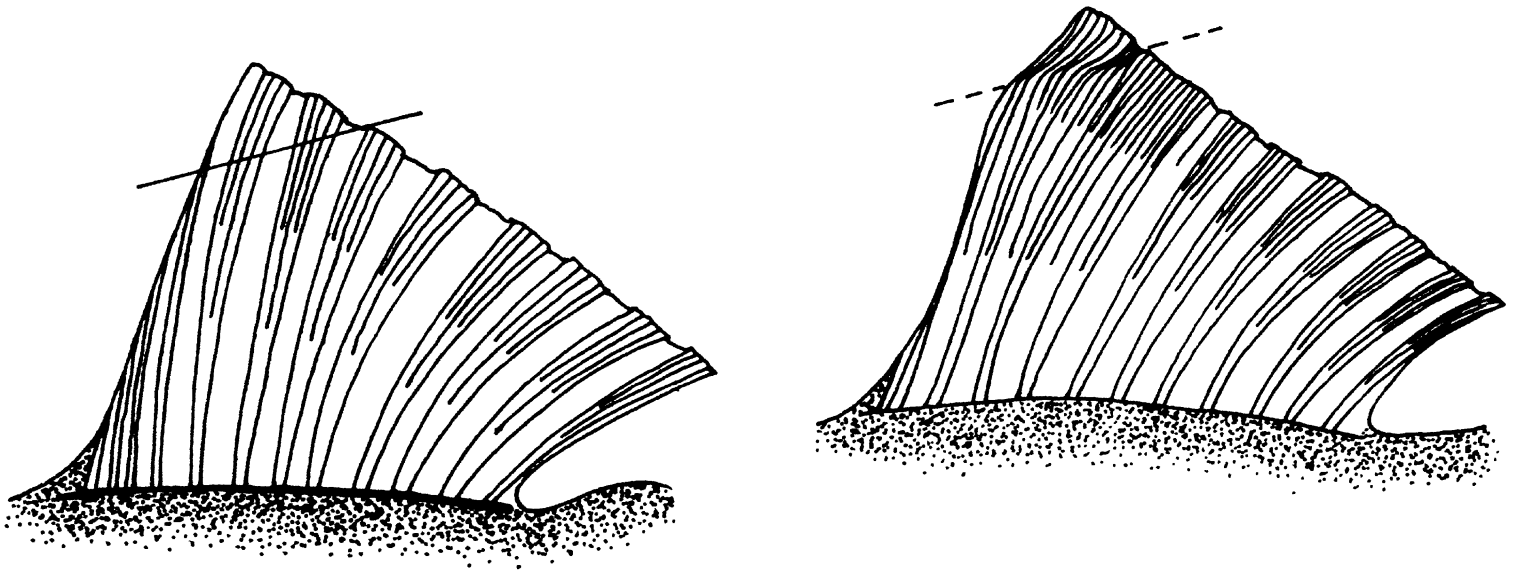
Riley (1966) describes latex marking of 0-group flatfish. The latex is introduced using a 1 ml Luer lock hypodermic syringe. The Luer lock prevents the needle bursting off the syringe either during the preparatory process of coating the inside surface of the needle with silicone grease or in the actual injection. About 200 fish can be marked with each ml of latex even allowing for wastage between injections. A 0.5 mm diameter hypodermic needle, 19 mm long, is the finest through which the latex will readily flow. A larger needle leaves a larger wound and is suitable only for flatfish longer than 3 cm.



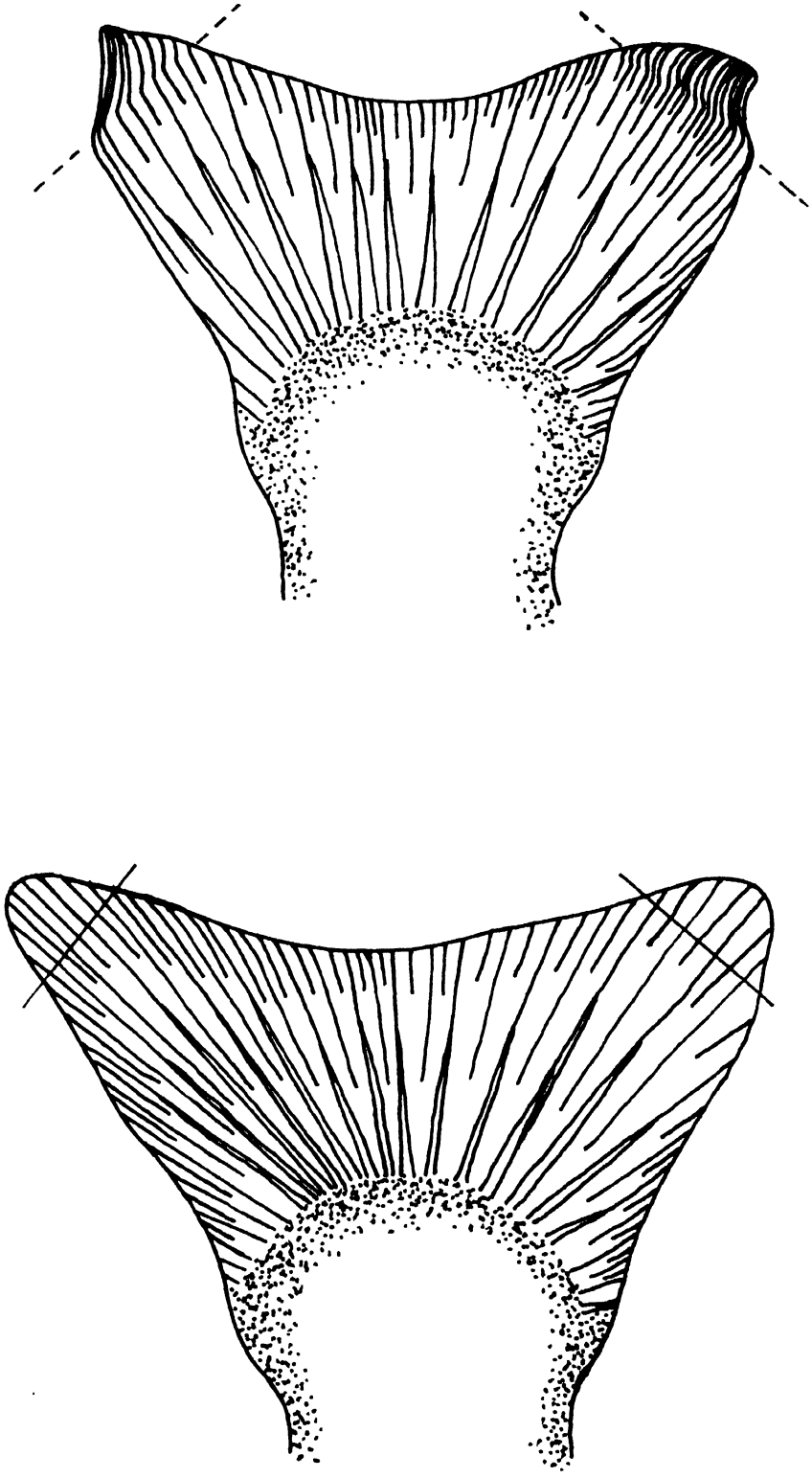
a) Fin is cut first along line a- - -a' and then, after regeneration, along line b- - -b'

b) Effect of making 3 cuts on same fi

Fig. 76 - Multiple clipping (Redrawn from Stuart, 1958)

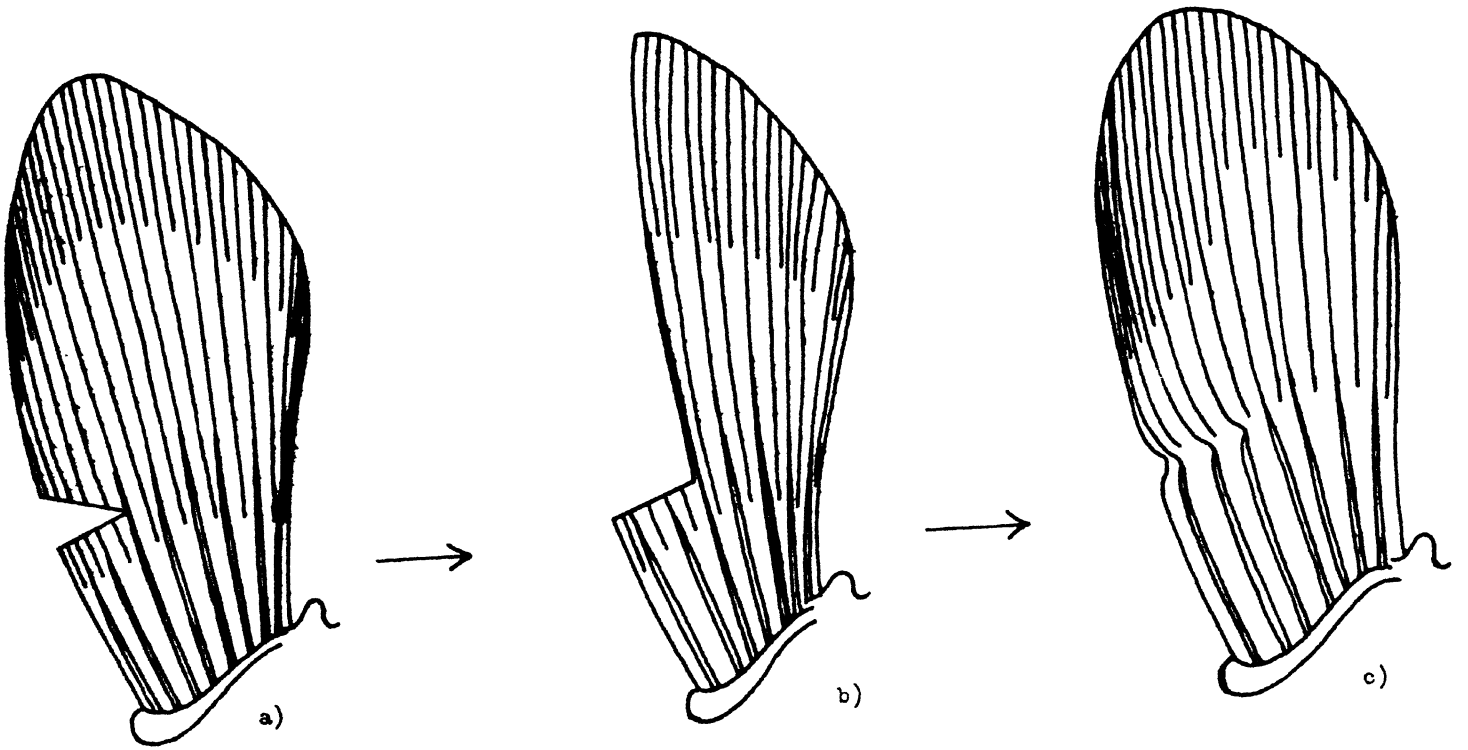


Figs. 77a and b - Effects of clipping dorsal fin
(Redrawn from Stuart, 1958)



Figs. 78a and b - Effects of clipping caudal fin
(Redrawn from Stuart, 1958)

Fig. 79 - Punching holes or cutting notches in fins can lead to almost complete regeneration (Redrawn from Stuart, 1958)



a - c - Regenerative sequence after cutting a notch (79a)

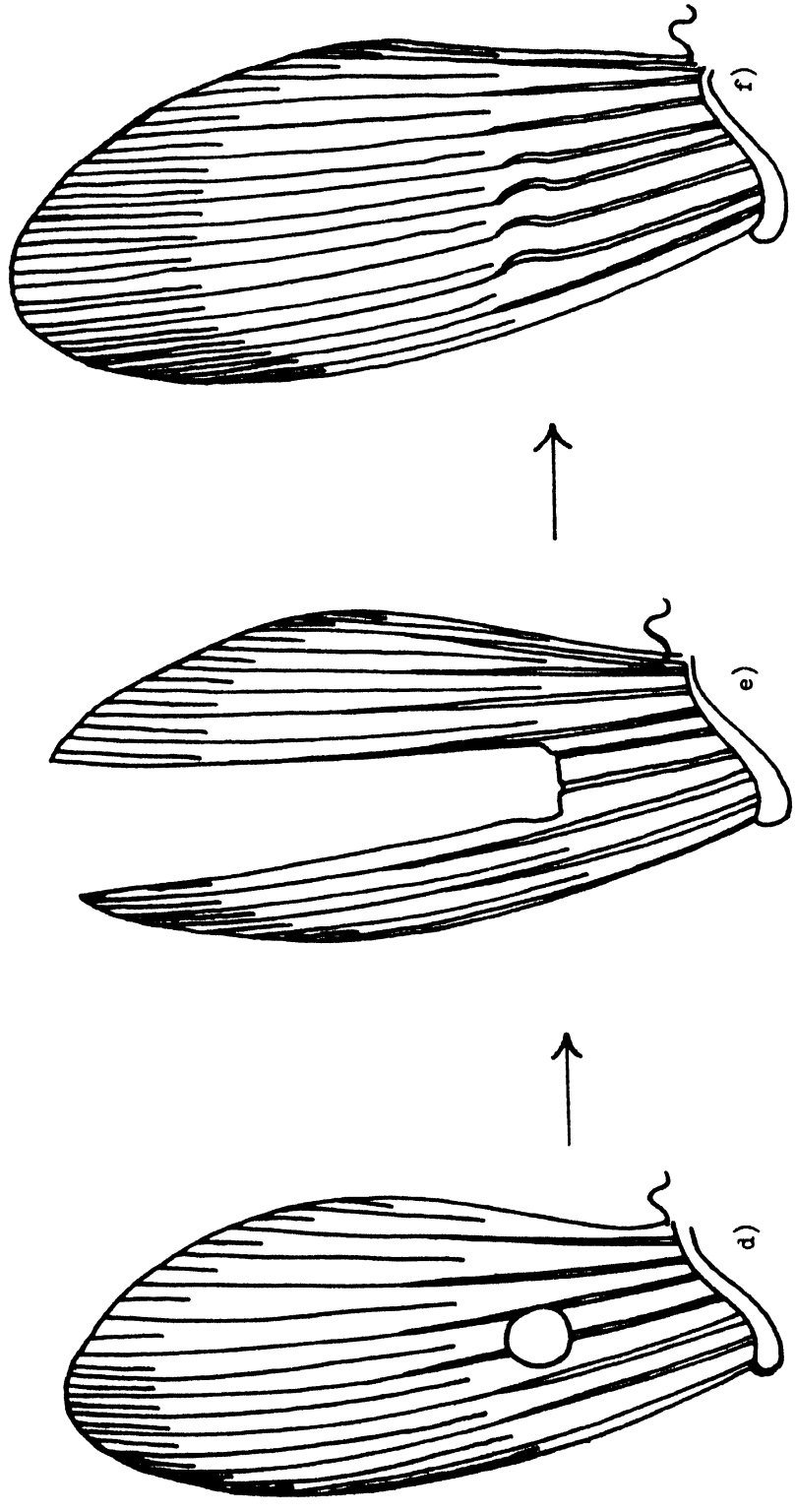
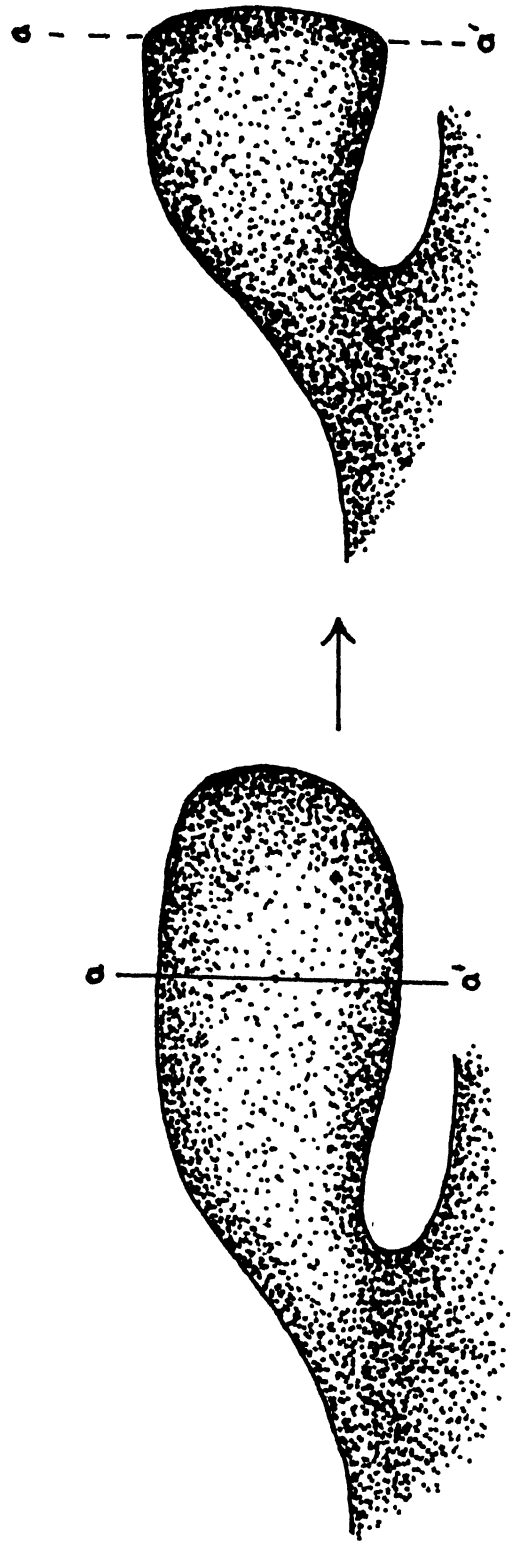
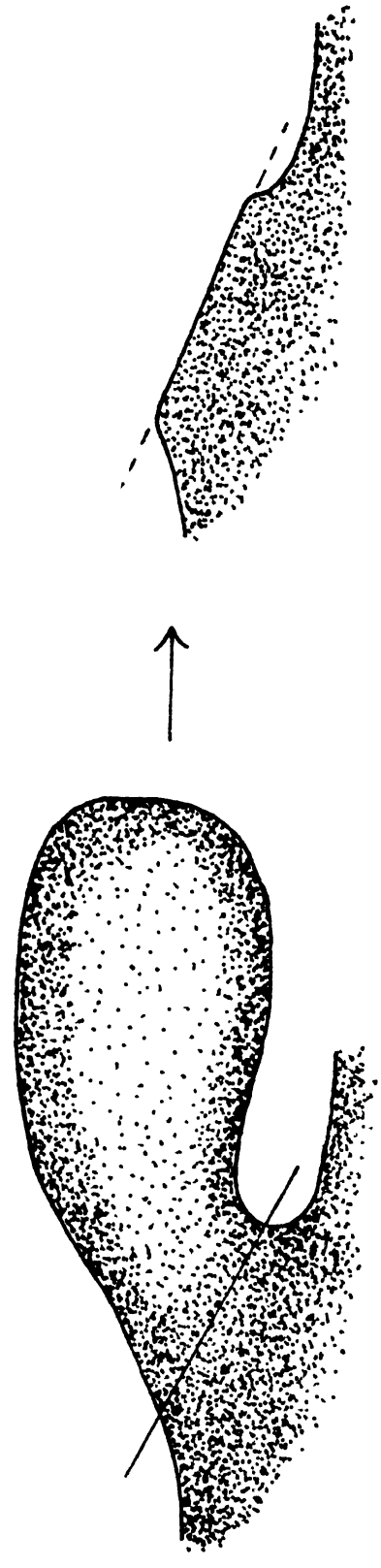


Fig. 79d - f - Regenerative sequence after punching a hole



Figs. 80a and b - Effect of cutting adipose fin along line a - - - a'



Figs. 81a and b - Effect of cutting adipose fin off at base
(Redrawn from Stuart, 1958)

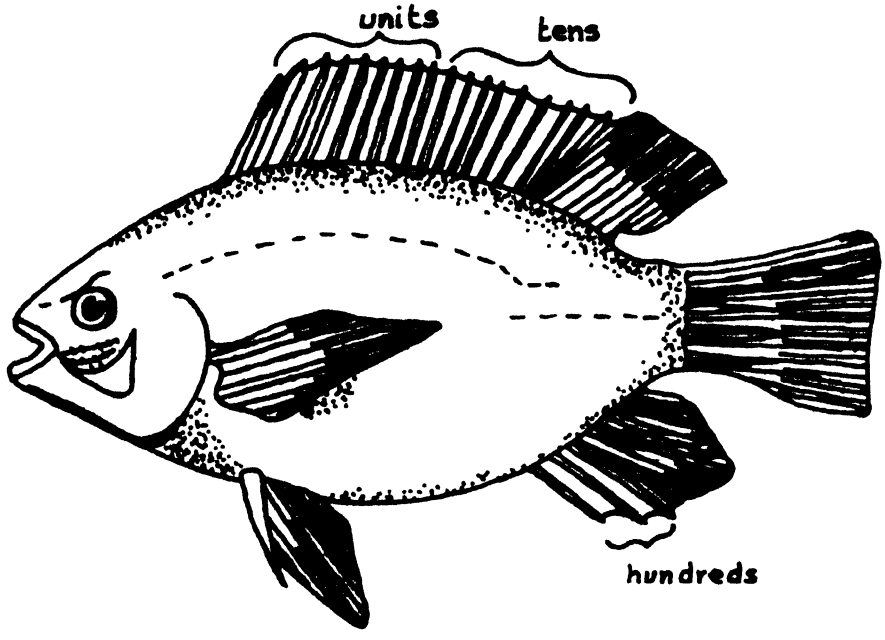


Fig. 82 - Coded spine clipping system used on Tilapia (Redrawn from Rinne, 1976)

After about 2 hours use the needle becomes blocked with coagulated latex and should be discarded. The needles should be greased with silicone grease between marking sessions. This prevents a rapid coagulation of the latex in the syringe needle and lubricates the syringe. For cleaning the syringe periodically during a prolonged marking session, and before storage, a 1-cm bottle brush and pipe cleaners can be used.

The most suitable latex is Diptex 319 and this can be obtained from Rubber Latex Ltd., Harling Road, Wythenshawe, Manchester 22. Six colours are available including red, yellow and blue. For further details see Riley (1966), Davis (1955), Arnold (1966) and Chapman (1957).

3.7.5 Tattooing

Hickling (1945) describes an electric tattooing needle. The needle is attached to a vibrator in a tube and is adjustable, so as to vary the length of needle point protruding from the tube. "In use the tube is held like a pen and is repeatedly dipped in the pigment like using pen and ink. The writing is done slowly with a moderate pressure on the skin and the needle, which vibrates at high speed, makes a series of fine punctures into which the pigment is carried. The whole device is simple and effective."

Hickling found "that it is easier to mark a living fish than a dead one because the fish responds to the irritation of the needle by producing mucus which washes away the surplus ink, and this makes it easier to see how much of the work has entered the deeper skin and therefore which of the strokes need to be repeated."

Hickling used 3 pigments, namely Chinese ink, natural sepia from cephalopods and Windsor and Newton's best quality vermilion which he mixed with water to make a very strong suspension. Hickling noted that after 7 weeks, 10 surviving plaice still had recognizable marks on them.

For further details see Hickling (1945), Arnold (1966), Dunstan and Bostick (1956) and Chapman (1957).

3.7.6 Radioactive marks

Scott (1961) gives criteria to be satisfied when using radioisotopes. These are:

1. The radioisotope element should have a physical half life that is reasonably long in relation to the fish's longevity.

2. It should be retained within the fish for a reasonably long time in relation to the fish's longevity.

3. It must emit radiation which is reasonably detectable with field equipment but at the same time with a low enough energy transfer to the fish to cause little or no biological damage.

Scott considered that iron-59 is a suitable radioisotope. This can be obtained in the form of $FeCl_3$ in HCl solution . The solution is diluted to a concentration of 5 microcuries per ml (μ/ml) with an acid solution of acriflavine hydrochloride (pH 2.25).

The solution is injected into the body cavity, the acriflavine being incorporated to prevent infection. The injections are made through the ventral body wall just anterior of the ventral fins, great care being taken to avoid puncturing any of the organs. It was found that 10-cm trout could be injected at the rate of 5 per minute using a 1-ml tubercular syringe with number 25 needles. No anaesthetic was necessary.

Two methods of radioassay were used. In one method, the tip of a Nuclear-Chicago Corporation DS8-16 mm needle scintillation probe was placed over the heart-liver region and the counts made with a portable rate meter. In the other method the fish were kept in an annular tank with a detector (a special gamma ray - sensitive Geiger-Muller tube) at the centre so that the fish were always in the same geometrical relationship to the probe. Providing that a radioisotope that emits hard gamma rays is used the second method is superior to the first, since the fish do not have to be handled (Scott, 1961).

For further details see Scott (1961), Seymour (1957), Arnold (1966) and Wilimovsky (1963).

3.7.7 Freeze branding

Jones and Geen (1976) describe experiments on freeze branding of spiny dogfish. "The marks consisted of numbers which were applied with two sizes of brass branding "irons" attached by thin steel rods to wooden handles. The larger numbers were about 2 cm high, 1.5 cm wide, and 0.3 cm thick and the smaller ones 0.8 cm high, 0.6 cm wide, and 0.15 cm thick. Branding temperature (- 196° C) was attained when the irons were immersed in an insulated canister filled with liquid nitrogen until the "boiling" action ceased."

"Brands were applied just below the first dorsal fin. After the excess moisture was removed, the irons were held against the skin for 2-5 sec. Anaesthetics were not used and the fish quickly resumed normal activity when they were returned to the water."

"Seconds after branding, the mark became almost invisible, but it gradually reappeared during the following week. Three months after branding for 2.5-sec with the larger irons, the brands were clearly visible. After 5 months, 5-sec brands were still easily recognizable under water. After 7 months 3-sec brands began to fade and pigmented tissue began to grow inward from the periphery. At 10 months, 3-sec brands were difficult to distinguish, but 5-sec brands were still discernible. Although the smaller irons left a persistent mark the numbers were difficult to distinguish on dogfish."

"When applied to other elasmobranchs, the large brands were effective only when applied to skin lacking mucus and spines. Thus, brands on brown cat-sharks (Apristurus brunneus) were easily readable, whereas those on big skate (Raja binoculata) were poor."

Jones and Geen conclude that "freeze-branding with liquid nitrogen can be used to distinguish individual elasmobranchs having a relatively smooth, nonmucous skin".

3.7.8 Electro-cautery

Branding fish with a hot wire, usually heated by electricity, has been used as a marking method particularly in fish hatcheries. According to Gerking (1963) fish can be easily branded using a hot wire but the brand has a limited longevity.

Johnson and Fields (1959) marked steelhead fingerlings about 4½ inches long with a branding tool of nichrome wire about 1½ cm in length. This was heated to a white heat with a 4-Volt AC wire. On contact with the fish a cut-off time was activated (manually) and this broke the heater circuit for one second.

Fleener (1958) used a 23-gauge Chromel A wire mounted in a handle. The power source was from a battery or 115-Volt alternating current. With the alternating current a transformer delivered 6-Volts at 5 or 6 Amperes to heat the wire. This tool was used to burn fins of small-mouth bass fingerlings 2-6 inches in length. They were anaesthetized before treatment.

3.7.9 Sonic tags

A sonic tag is essentially a miniature transmitter. This makes it possible, using appropriate equipment, to follow the movements of an individual fish. Trefethen (1963) describes a tag capable of producing a tracking signal for 24-60 hours in fresh water at a range of 500-1 200 ft. In salt water the range is reduced to about one third. The dimensions of the tag are 46 mm long and 15 mm in diameter. The tag can only be used on comparatively large fish, therefore, such as adult salmon or large cod. See also Walker et al. (1971) and Laurs et al. (1977).

3.7.10 Tetracycline marks

Tetracycline drugs, when injected into fish, are laid down in the hard skeletal parts such as the scales and otoliths. When irradiated by ultra violet light these can usually be detectable as bright yellow marks. The technique has been used for investigating the growth of skeletal parts. By noting the amount of new growth that takes place during a known interval such as that between marking and recovery, the growth of the skeletal part can be measured.

The exact dosage is important since with too small a dose the mark is not readily detectable but with too large a dose a rather broad and indistinct mark is produced. The appropriate technique is to experiment with different dosages until a dose producing a thin but readily detectable mark is produced. See also Arnold (1966).

3.7.11 Fluorescent tags

Leaman (1976) used a fluorescent tag for following the movements of black rockfish visually. The tag consists of a nylon anchor tag to which is fixed a length of 5 mm glass tubing filled with powdered sodium fluorescein dye. The glass tube is closed at one end with quick drying epoxy glue or silicone sealant. Dye diffuses from the tag as the fish swims away enabling its progress to be followed visually by an observer on the surface or by a diver in the water.

3.8 Biological tags

Some animals may be distinguished by the presence or absence of natural parasites or by particular meristic characters. Under favourable circumstances, such "biological" marks or tags may be used instead of having to resort to artificial marks.

3.8.1 Parasitic infection

Hare and Burt (1976) investigated parasite species on Atlantic salmon smolts. They used the presence or absence of particular species to identify the rivers from which the smolts had originated.

Platt (1976) showed that larvae of the codworm Terranova decipiens were virtually absent from cod in Greenland but abundant in Iceland. The reduction in the characteristic level of infestation at spawning time (on the spawning grounds off south-west Iceland) was thought to be due to immigration of uninfected cod from Greenland waters.

Kabata (1963), working with haddock, used gall bladder Myxosporidia to confirm that there was little, if any, exchange of fish between:

1. The Faroe Plateau and the North Sea, and

2. The Faroe Plateau and the outlying Faroese banks.

Templeman and Fleming (1963) used the distribution of Lernaeocera on cod as an index of cod movement in the Newfoundland area. They found that infestation with Lernaeocera was highest in the inshore area, the infestation declining approximately in proportion to distance from shore. There was none on Flemish Cap and very little on the southeastern parts of the Grand Bank. The interrelationships of the cod stocks in the region deduced from a study of parasites (see also Templeman et al., 1957, on the incidence of nematodes) were similar to those indicated by tagging and meristic studies.

Pippy (1969) looked at Atlantic salmon to determine which parasites might be useful for investigating the continental origin of salmon in Greenland.

3.8.2 Meristic characters

In some situations there may be natural meristic difference between populations that may be used to provide information about probable origin. This information should be used with care, however, since statistical variations in the chosen characters may make it difficult to interpret such data reliably.

3.8.3 Blood groups

Natural variations in blood groups can sometimes be used to differentiate subpopulations of fish (e.g., Marr and Sprague, 1963; de Ligny, 1967; Fujino, 1970).

3.8.4 Others

Other natural recognition marks may be used as biological tags. For example, Boddeke (1975) notes that in the brown shrimp (Crangon crangon), the females with abdominal eggs form a discrete group from July to October, since no recruitment to this group takes place during this period. The distribution of these animals can be monitored for several months and this can provide useful information about shrimp movements.

3.9 Marking invertebrates

Many of the methods described above can be, and have been, used on invertebrates. Additional notes on particular species and groups of species are given below.

3.9.1 Shrimps

Details of methods for marking shrimp are given by Neal (1969). He deals with staining by injection, feeding and immersion, as well as external and internal tags.

"If a quantity of stain of less than 0.1 ml is injected into each shrimp, a small tuberculin syringe, with a 6.35-mm, 30-gauge needle is used. If more than 0.1 ml is injected, the use of a continuous pipetting output equipped with a 1-ml Luer-Lok syringe and a 26- or 27-gauge needle facilitates the injection procedure." (Neal, 1969) (Fig. 83)

Fig. 84 shows the method recommended by Dawson (1957) for injecting a shrimp. The needle is inserted through the articular membrane of the sixth abdominal joint.

Marullo et al. (1976) used a vinyl streamer tag for shrimps (Penaeus sp.). The streamer tags (Fig. 37) are 2 mm wide and 150 mm long, cut from clear vinyl 0.1 mm thick. A No. 7 Crewel stainless steel needle is cemented to one end of each streamer with industrial adhesive, and a coloured tab of vinyl is cemented to the opposite end to enhance recognition. The needle is inserted through the abdominal musculature and the streamer drawn through until equal lengths protrude on each side of the shrimp. The needle is then detached. The tag is inserted through the articular membrane between the first and second abdominal segments to reduce interference with ecdysis. These tags were found to be superior to the Petersen tags for two reasons. First, shrimps can be tagged more easily and rapidly. Second, tagged individuals regain equilibrium and begin swimming actively much sooner than those tagged with Petersen tags. The streamer tag is light and flexible compared with the Petersen tag. There is also the danger that if an excess length of wire is left on a Petersen tag pin, to allow for shrimp growth, it may shift to one side and the resulting change of balance may impair swimming and burrowing activities (Fig. 85). Lindner and Anderson (1956) and Neal (1969) recognized that a high mortality is associated with the use of the Petersen tag on shrimps. On the other hand, mortality in shrimps tagged with a streamer may not differ significantly from that of an untagged shrimp (Marullo et al., 1976).

3.9.2 Crabs and lobsters

Simpson (1963) describes the tags used on crabs and lobsters. He notes that, with the possible exception of the king crab, it has not yet been possible to develop a tag for crabs and lobsters that remains attached through a moult. Some tag details are shown in Figs. 86a, b and 87a, b).

In the case of king crabs the problem of avoiding tag loss at moulting time seems to have been solved by using a spaghetti tag threaded through the arthral muscle at the junction between the carapace and the abdomen. "For tagging, the carapace and abdomen are spread to expose the isthmus. The tag is then threaded through the muscular part of the isthmus with a curved stainless steel needle. Care must be taken to avoid the large blood sinuses anterior to the muscular part. The two ends of the tubing are brought together and tied in an overhand knot. Sea water appears to be necessary for blood coagulation and it is important that the crabs are returned to the sea as quickly as possible. Recovery from tagging appears to be rapid." (Hayes, 1963).

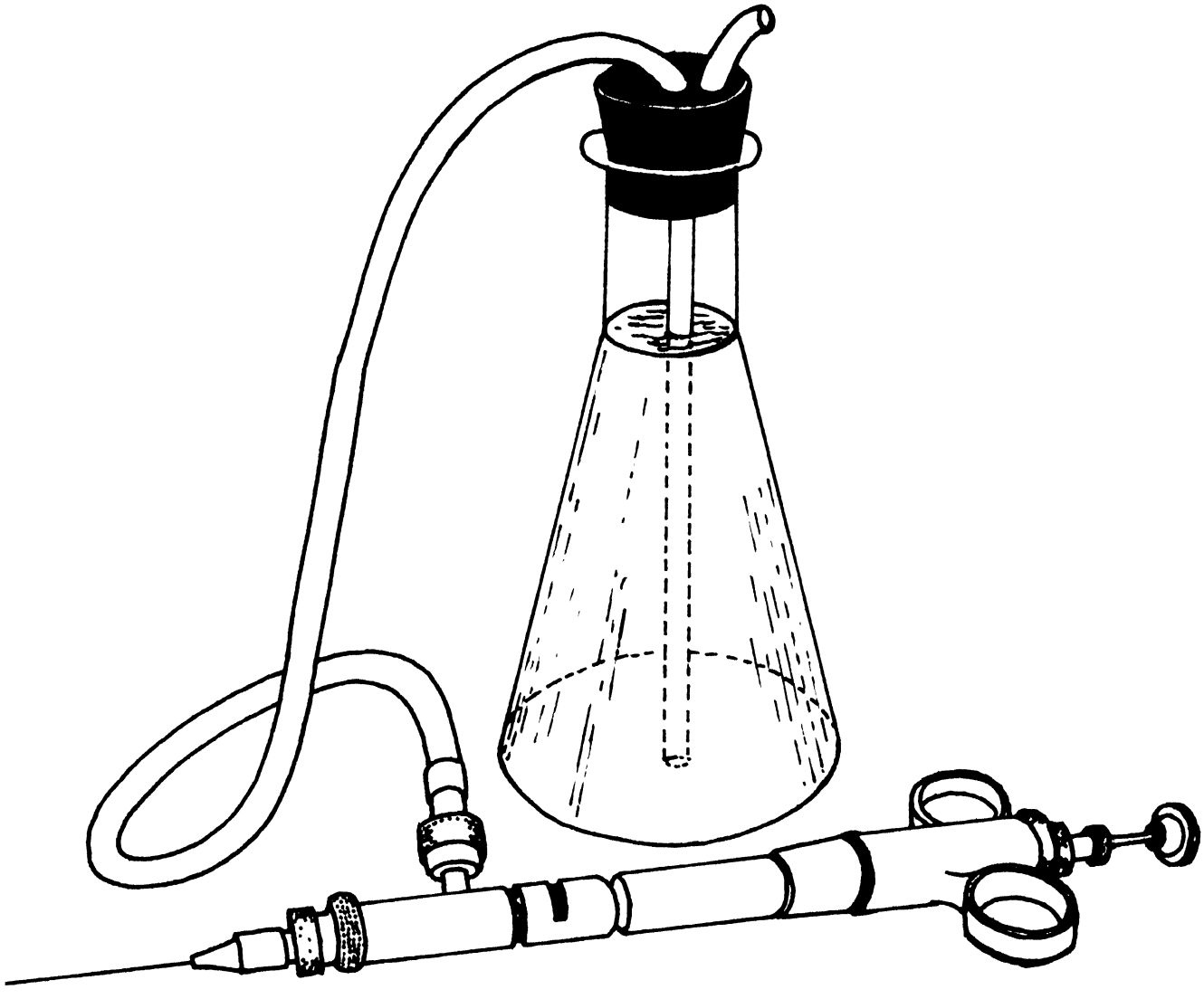


Fig. 83 - Syringe and continuous pipetting outfit for injecting dyes (Redrawn from Neal, 1969)

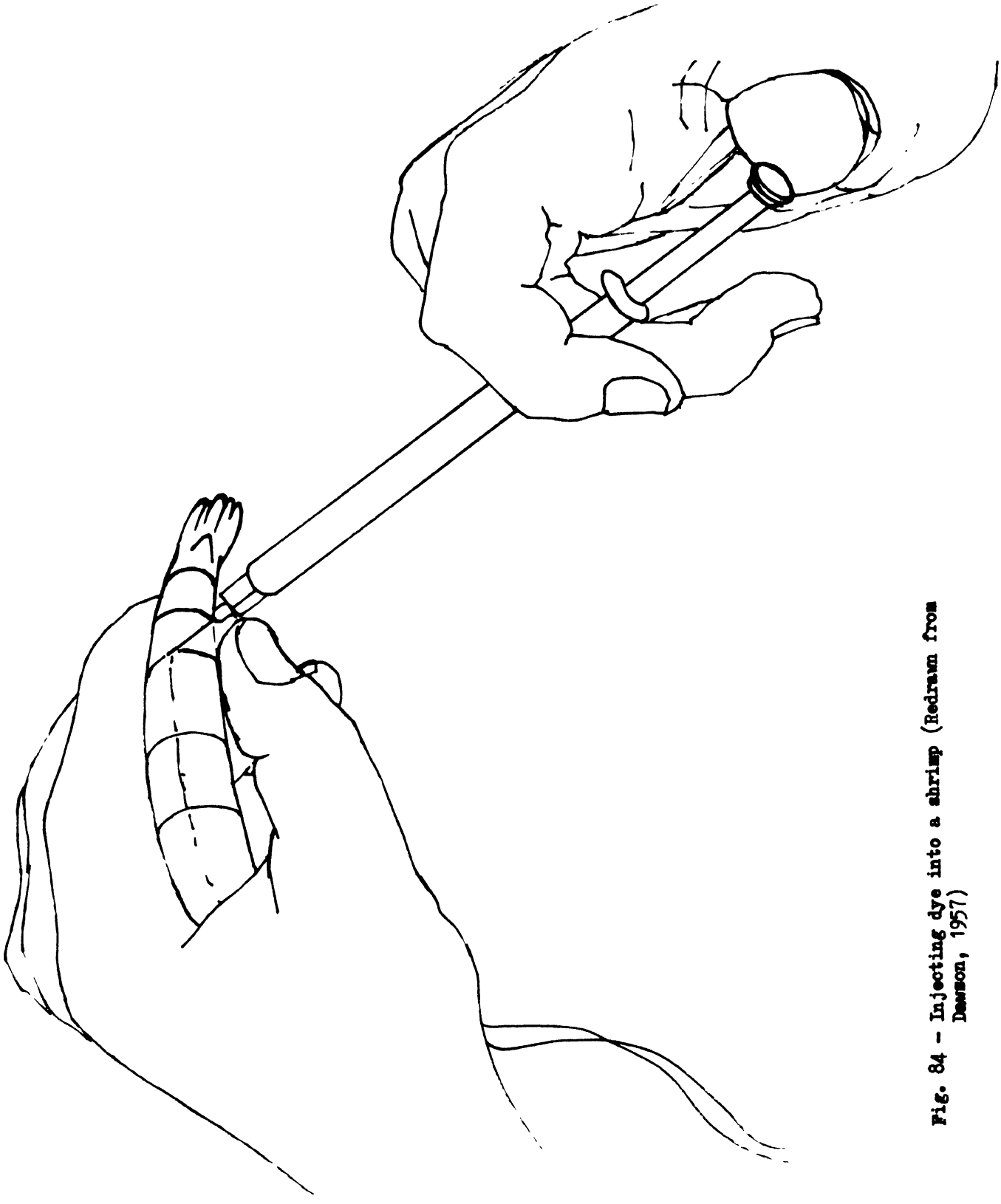


Fig. 84 - Injecting dye into a shrimp (Redrawn from Dawson, 1957)

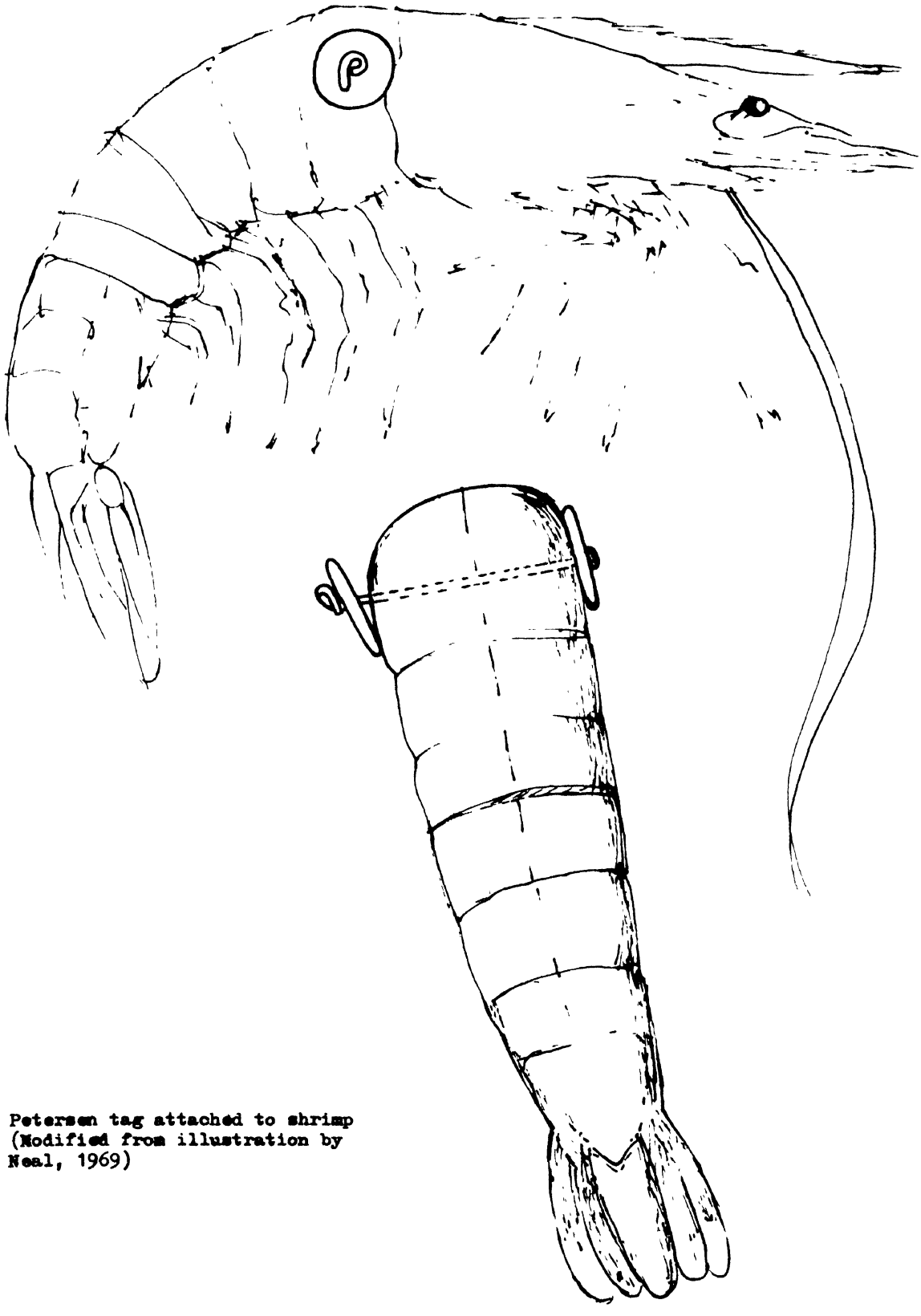
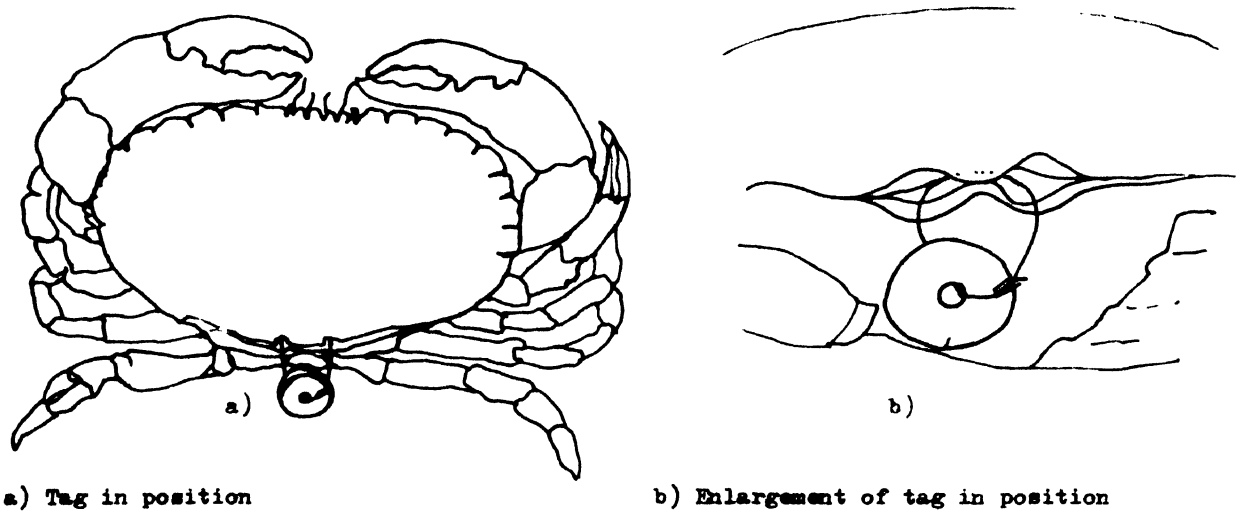


Fig. 85 - Petersen tag attached to shrimp (Modified from illustration by Neal, 1969)



a) Tag in position

b) Enlargement of tag in position

Fig. 86 - Tagged crab (Redrawn from Edwards, 1971)

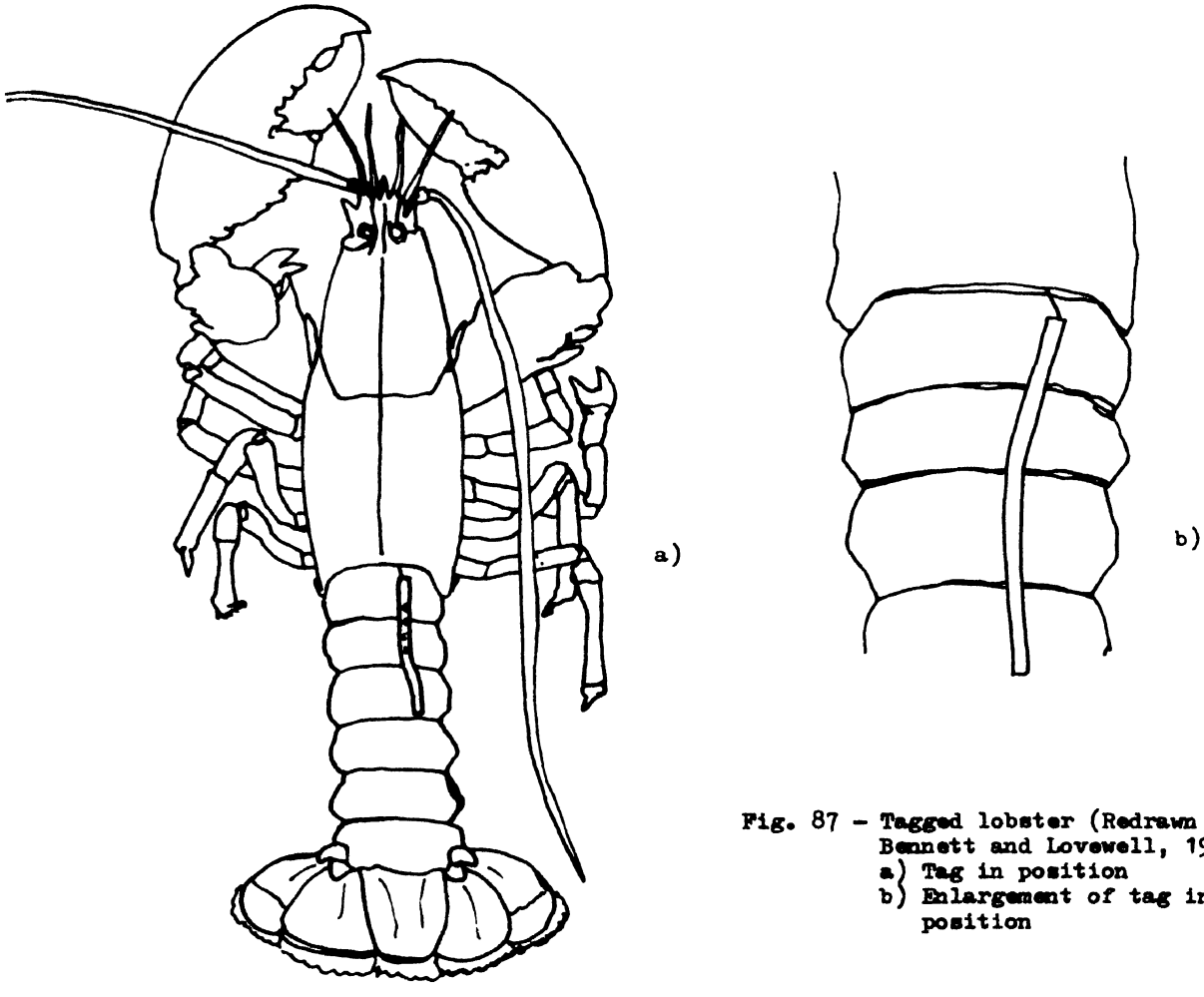


Fig. 87 - Tagged lobster (Redrawn from Bennett and Lovewell, 1975)
a) Tag in position
b) Enlargement of tag in position

Cleaver (1963) notes that only crabs with firm shells should be tagged. When newly moulted and soft, the crabs are easily damaged.

3.9.3 Squid

Squid can be tagged by attaching external tags to the mantle. Park and Lim (1967), for example, used an arrow tag for squid tagging (Fig. 88).

3.9.4 Shelled molluscs

Hancock and Urquhart (1959) describe methods of marking whelks. These include painting the shell or attaching numbered paper labels by adhesive to the shell (Fig. 89). For painting, a quick-drying paint was used and combinations of different colours used for identification purposes. The whelks were placed in containers of sea water for a short time after the paint had dried to reduce the time needed for them to recover and thus to minimize post-marking mortality due to attacks by crabs and other predators. The colours of paint were selected for their brightness. In most cases the paint was still bright and in good condition on whelks recaptured even after one year.

Posegay (1963) describes tagging of the sea scallop. "There is a deep byssal notch in one ear of the lower valve which is not present in the upper valve. A touch causes the scallop to withdraw the mantle and a fine hole is drilled in the upper valve just above the byssal notch. A stainless steel pin bearing a numbered Petersen disc is pushed through the hole and bent over to hold it in place."

Thomson (1963) shows how Petersen discs can be cemented to scallop shells for tagging purposes (Fig. 90).

4. RELEASING THE FISH

In many situations it is sufficient to release the fish into the water immediately after tagging. When dealing with physoclistous fish from deep water, however, there is a likelihood that some fish will have inflated swimbladders and be unable to dive due to their increased buoyancy. This can lead to difficulties, e.g., exhaustion due to unsuccessful attempts to submerge, or predation by sea birds. In this situation the use of a lowering cage may be essential.

Sandeman and Rees (1963) describe a lowering cage that they used for redfish. This consists of a cubic metal frame of angle iron about 1 m on a side. The framework is covered with netting to form a cage (Fig. 91a). "This is lowered into the water on a hydrographic wire. Entrance to the cage for loading purposes is provided by a small trap door in the upper surface and this is tied shut when the cage is lowered. Tagged fish are allowed to escape by means of a second larger trap door consisting of almost one complete side of the cage. This is kept closed by means of a spring loaded line connected to a messenger-operated release mechanism of the type normally used for closing plankton nets. On being released the trap door, which is hinged at its lower edge, falls open due to gravity, a short weighted arm being fixed to the door to assist this." (Fig. 91b).

In dealing with buoyant fish it may be sufficient to use a cylindrical release cage open at the bottom. The fish can be placed into the container through an opening at the top. When it is ready to lower, the top is closed (Fig. 92a) and the container lowered to the bottom (Fig. 92b). At the bottom, due to the increased pressure, the fish lose their buoyancy and are able to swim down and out of the cage before it is hauled back to the surface. To ensure that fish do not escape from the cage while it is still at the surface, the cage should be large enough for the bottom to extend some distance below the surface (Fig. 92a). This has the advantage that those fish that can dive deeply enough to escape from the cage can do so. Only the buoyant fish that need to be lowered are then left inside.

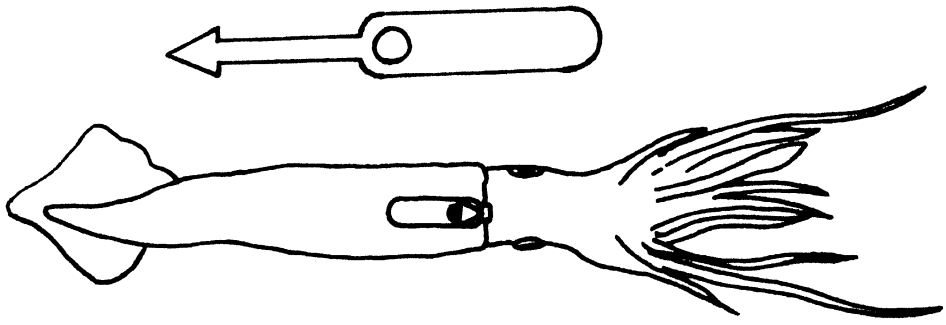


Fig. 88 - Tagged squid (Redrawn from Park and Lim, 1967)

Fig. 89 - Painted whelk (Redrawn from Hancock and Urquhart, 1959)

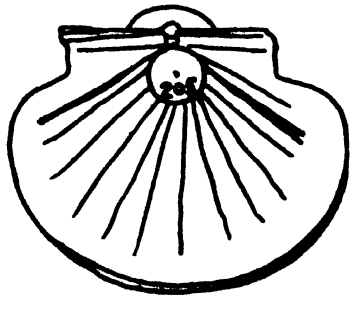


Fig. 90 - Petersen discs cemented onto scallop (Redrawn from Thomson, 1963)

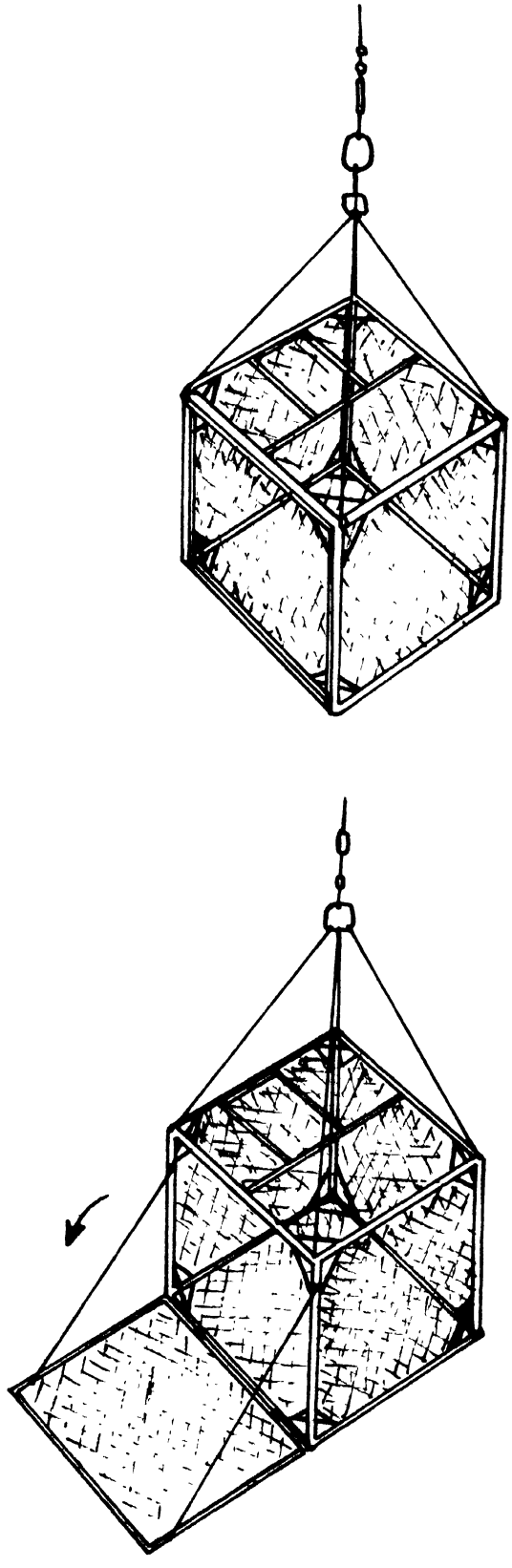


Fig. 91 - Lowering cage
(Redrawn from Sandeman and Rees, 1963)
a) Cage closed
b) Cage open

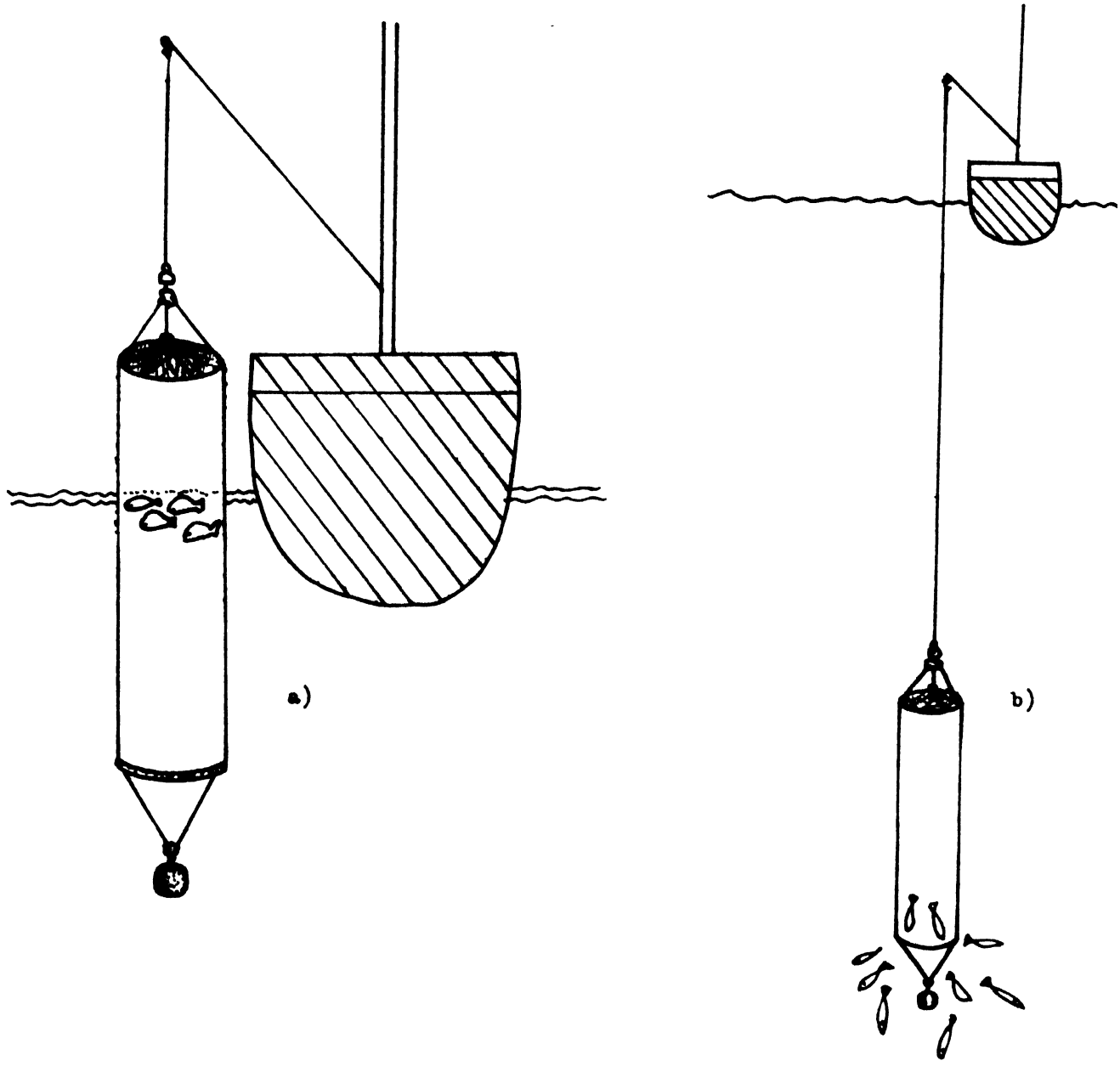


Fig. 92 - Lowering cylinder
(Modified from illustration by Sandeman and Rees, 1963)
a) Cage at surface - bottom open but fish too buoyant to swim down and out
b) Cage lowered down - increase in pressure allows fish to swim down and out

Hislop (1969) avoided the need for a lowering cage by tagging fish underwater and then transferring them to an underwater cage for a period before releasing them (Fig. 93).

When small schooling fish are marked, they should be released in groups from a holding tank (see section 2.2.2).

5. RECAPTURE OF MARKED FISH AND RECOVERY OF TAGS

5.1 Stages in the recovery process

Margetts (1963) noted that, in the major part of the British fishing industry, the five stages at which a tagged fish can be recovered are:

1. on the ship at sea by the fishermen handling the fish
2. on the quayside by a docker discharging, sorting and weighing the fish
3. on the premises of a wholesaler, packing and filleting the fish
4. at a retail shop
5. in the home of a consumer.

Margetts investigated the efficiency of capture at different stages by planting tagged fish both on board ships and on the fish market. He concluded that the overall recovery rate ashore was not more than 50%.

5.2 Variability of return rates

Return rates can vary considerably both between different areas and between different countries. For example, Horsted (1963) compared the recovery rate of cod tags by Portuguese fishermen. He considered that because dory-caught cod are handled individually to a much greater extent than trawl-caught cod, it is likely that Portuguese dory vessels yield a much higher percentage recapture rate than trawl vessels.

McCracken (1963), working with cod, noted that the numbers of returns per unit landing varied markedly for different countries. He thought that this was probably the result of differences in tagging publicity and handling procedures.

Hancock (1963), working with whelks, was able to show that the returns per unit of effort were consistently above average for some fishermen than for others.

5.3 Tag visibility

Many workers have stressed the importance of the visibility of the tag to ensure that it is seen by the fishermen when being handled.

De Veen (1963), working with plaice, noted that the return rate of Albrechtsen tags is considerably lower than that of Petersen discs. He thinks this is because the Albrechtsen tag is more easily overlooked because of its shape, colour and location on the body of the fish. He notes that this difference does not apply to sole, because of the greater individual attention given to sole on board Dutch fishing vessels.

Broadhead (1959) tested different colours of spaghetti tags on tunas. A comparison of different colours showed the advantage of yellow over clear and white vinyl tubings. A considerable number of workers have emphasized the importance of bright colours such as orange, red and particularly yellow. A number of workers have stressed the value of having trailing ends to a spaghetti tag or vinyl streamer to make the tag more conspicuous.

5.4 Improving efficiency of reporting

The efficiency of reporting can be improved in a number of ways:

1. Each tagging experiment should be widely publicized. This can be done through press and radio, through the use of newsletters, by posting notices on wharfs and distributing posters to fishermen and fish merchants.

2. To ensure that the desired information is returned, it may be appropriate to distribute special tag return forms.

3. It is customary to issue a reward for every tag returned. The value of this should be clearly stated both on posters and in newsletters and also on the tag itself. It is essential that there be enough writing on each tag to make it clear that there is a reward and exactly whom the fisherman should contact to get it. When a tag is returned, the reward must be paid at once.

4. When the fish as well as the tag is returned, it is usual to refund the value of the fish.

5. If possible, it is desirable to employ someone to interview fishermen, to ask for tags, and to establish good relationships with them.

Further interest may be stimulated in various ways. For example, many fishermen are interested in the movements of tagged fish. It may be useful, therefore, in addition to the reward, to give details of the movements of the tagged fish and perhaps a summary of tag experiments to date. Apart from giving rewards, additional interest may be stimulated by having a lottery based on the tag numbers (Hylen, 1963). Prizes for lucky numbered fish can be donated and public drawings can be held. Other "handouts" may be appropriate. For example, Collyer and Young (1953), working with kelp bass, provided fishermen with a wallet-sized plastic commendation card engraved with a brief history of the fish and the name of the fisherman. The actual tag was embedded in the plastic of the card.

5.5 Internal tags

Internal tags present particular problems. They are frequently made of magnetic material so that they can be detected by magnetic separators in fish meal plants. There are three important factors causing failure to recover these tags. These are:

1. The tags may be lost in the machinery before they come into contact with the magnets.

2. The magnets may not attract and retain all the tags that pass over them.

3. The tags may be lost during the process of clearing tags and metal from the magnet (Clark and Janssen, 1945).

Experience shows that each of these sources of loss can vary between plants, even within the same fishery. These are factors that cannot be eliminated and should be allowed for by a special "seeding" experiment designed to estimate these sources of tag loss. Seeding consists of planting known numbers of fish on board vessels and at various points within a fish meal plant in order to provide estimates of the percentages returned from different stages in the recovery process and the time required for tags to appear at different stages.

For fish such as herring, one of the important species that is tagged internally, a certain proportion of the catch is delivered directly for human consumption. Various detectors have been developed to deal with this problem and one device for detecting internally tagged individuals in a stream of fish delivered to a fish landing place is described by Gytre and Jakupsstovu (1977). In this system (Fig. 94a), all fish are transported up a

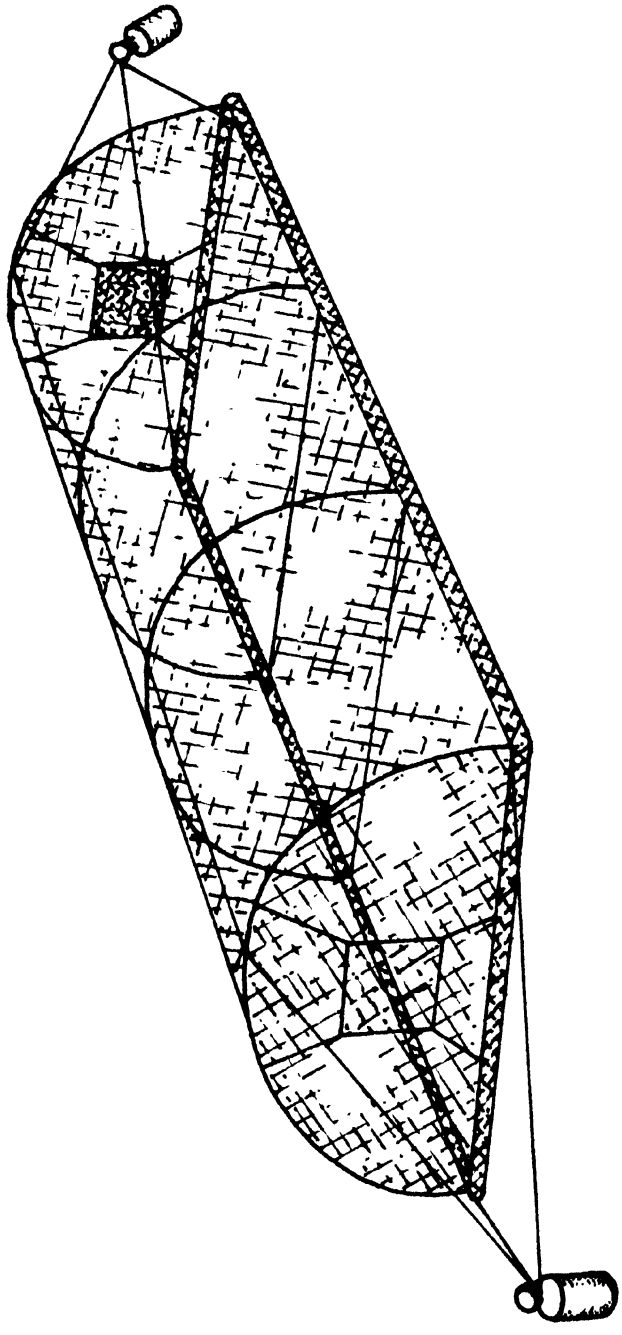


Fig. 93 - Underwater holding cage (Redrawn from Hielop, 1969)

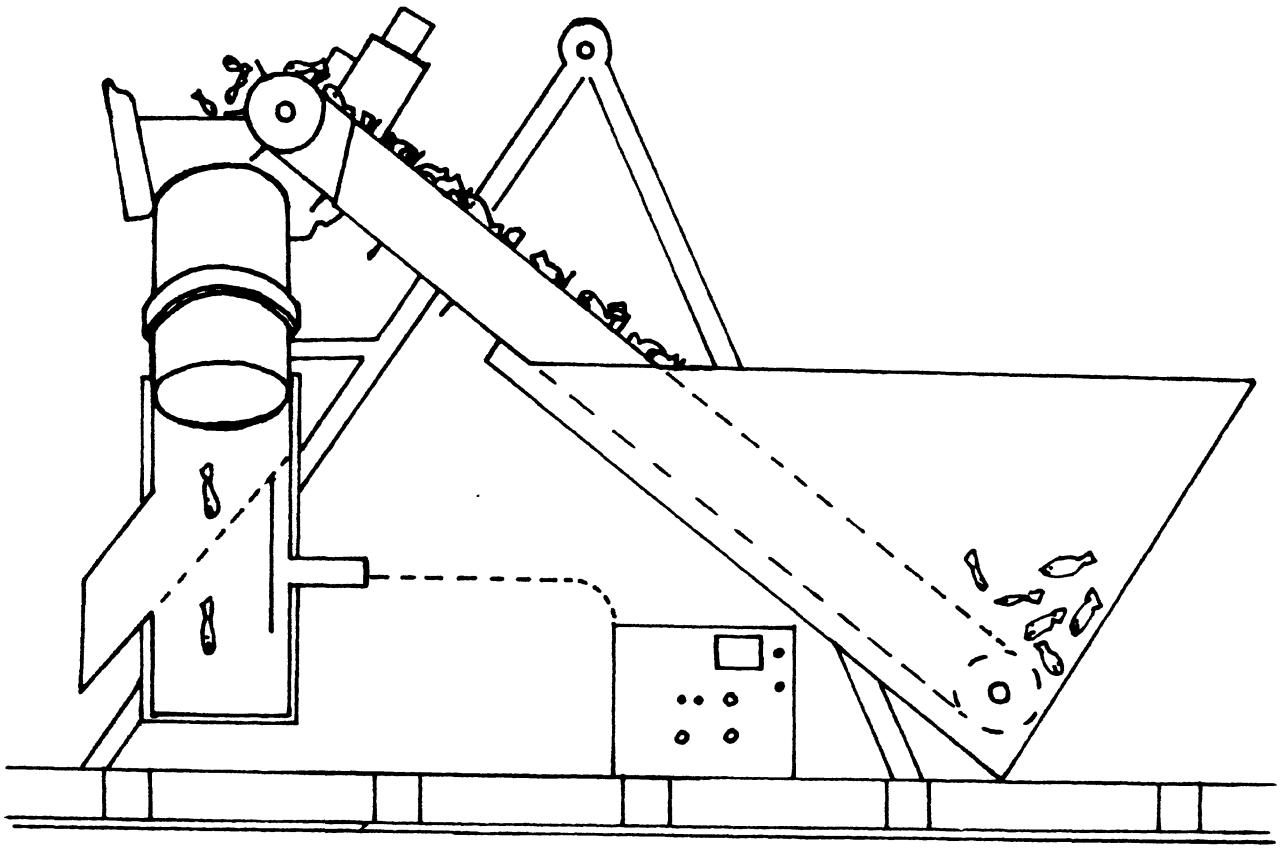


Fig. 94 - An arrangement for detecting internal tags in fish (Redrawn from Gytre and Jakupsstovu, 1977)
a) Fish raised on conveyor belt and allowed to fall through detection device

conveyor and then dropped through a tube to which a magnetic tag detector is attached in the form of a collar (Fig. 94b). When a tag is detected, a signal opens a gate below the detector so that the tagged fish and others with it drop into a collector. Otherwise the gate remains closed and untagged fish pass on to the processing line.

A portable instrument for the location of suboutaneous fish tags is described by Moore and Mortimer (1954). It comprises a search coil on a flexible cable as part of an oscillator circuit, the frequency of which changes slightly when the tag is approached.

Fish bearing non-magnetic internal tags may be recovered by placing an external tag on the fish as well.

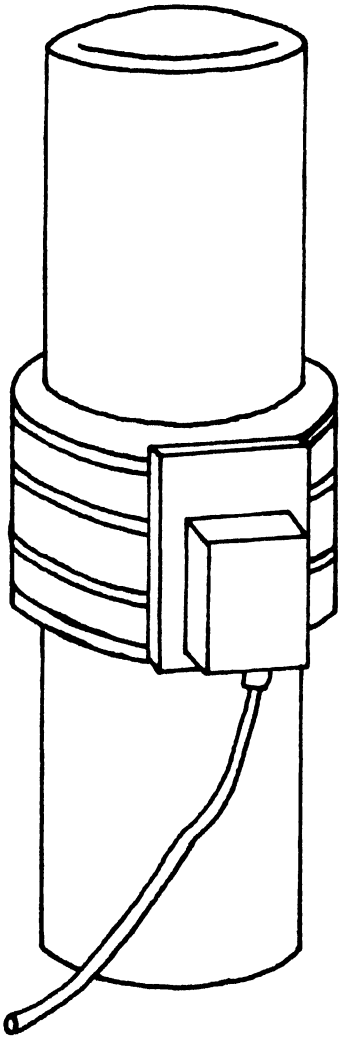


Fig. 94b - Enlargement of detection device

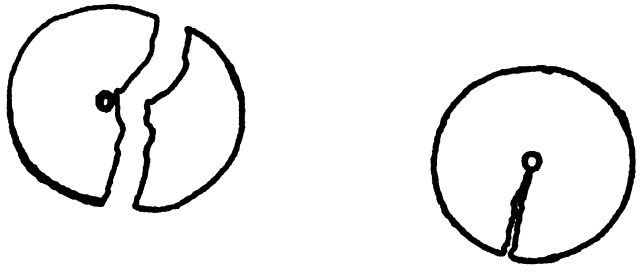


Fig. 95 - Cracked and broken Petersen discs (Redrawn from Calhoun et al., 1951)

6. FACTORS RELATED TO FISH SURVIVAL AND TAG LOSS

Tags may be lost, either directly because they fall off the fish, or indirectly because the fish die. The principal factors involved are considered below:

6.1 Deterioration of tags and attachments

Not all tags and their attachments have equal durability. Some results are considered below.

6.1.1 Corrosion of wires

Forrester and Ketchen (1955) made observations on the metal used for attaching Petersen tags. They found that nickel pins were most subject to corrosion or wear, with pins of silver wire or stainless steel being successively more reliable. Tagging wounds were worse with nickel pins and least with stainless steel wire. They considered that nickel pins were so bad that they were worthless for long-term studies.

With silver wire it was found that there was considerable thinning where contact was made with the tagging disc so that there was a tendency to break. In the case of nickel pins the source of weakness lies at or near the head and where the head was removed and replaced by a loop, the recoveries using nickel pins were substantially increased, at least during the short term (1-2 years).

Jensen (1958) showed that nickel pins mostly corroded where they passed through the operculum and where they were in contact with tissue. Stainless steel pins on the other hand were almost completely free from corrosion.

6.1.2 Deterioration of tags

Calhoun, Fry and Hughes (1951) investigated the deterioration of plastic Petersen tags. They found that "cellulose nitrate was most satisfactory although it can become brittle after prolonged storage. Thin cellulose acetate discs (0.8 mm) seemed satisfactory on flatfish but failed badly on salmon. Thicker ones (0.12 mm) stood up fairly well. Vinylite discs have proven unduly brittle and subject to cracking." (Fig. 95).

Broadhead (1958) found that vinyl plastic tubing weakens after immersion in sea water, possibly because of leaching of the plasticizer, so that many of the tags can be easily broken. Experiments showed that better return rates can be obtained using tags strengthened with monofilament nylon core. At very low temperatures vinyl tubing has a tendency to break but polyurethane tubing does not.

6.2 Tagging wounds

Experience shows that different methods of attachment can produce a variety of tagging wounds.

6.2.1 Tags attached to the operculum

Calhoun (1953) noted that when tags were attached to the operculum of striped bass, "sizeable holes are worn in the cheek quite rapidly even in the case of large bass with thick opercular bones. Only 8 out of 19 tags remained on experimental fish for 14 months and all were in an unsatisfactory condition".

On the other hand strap tags attached to the operculum of halibut in the north Pacific have proven very satisfactory, lasting for many years.

6.2.2 Tags attached dorsally

Williams (1963), working with plaice, noted that when tags are attached dorsally with braided nylon bridles there is a tendency for these to cut through the neural spines on which they are anchored and in some cases these can be sawn through completely.

Parrish and McPherson (1955) using toggle tags on herring found that the size of the wound varied according to the angle of the nylon at the point of emergence from the back of the fish (Figs. 96a and b). The degree of wounding was least in instances where the nylon ran approximately antero-posteriorly (Fig. 96a), and greatest when it made a large angle with the longitudinal axis of the fish at the point of emergence (Fig. 96b). In all instances the wound remained open but with no evidence of decay of the tissue. In the light of their observations they thought that tag shedding could have been quite high. Ancellin (1963) working with herring found that tags attached with nylon thread, especially when this is unbraided, tend to work themselves free by cutting the tissues of the fish.

Yamashita and Waldron (1959) reported that when tuna were tagged with dart tags, "the tagging wound healed rapidly with no infection. Scar tissue can be present within 10 days of tagging and well developed within a month. The scar tissue does not usually fuse to the tag but forms a tight, glove-like pocket round the head and streamer. The external wound can be small."

Hartt (1963) noted that "after 2 years at liberty, spaghetti tags were still firmly attached to salmon but the wound was elongated posteriorly because of chafing by the trailing portion of the tag." Hartt also used Petersen tags attached dorsally to salmon and records an instance where the growth of the fish caused the disc to migrate upward for about half of its diameter, leaving a path of smooth scar tissue in its wake as the fish grew. The wound was quite healthy, however, and there was no sign of the tag coming loose although the discs had become partially embedded in the flesh (Fig. 97).

6.2.3 Tags attached to jaws

Monel-metal jaw tags have been used on trout under hatchery conditions. After 10 months a number of deformities have been noted (Anon., 1957). Calhoun (1953) thought that jaw tags might interfere with feeding.

6.2.4 Tags attached caudally or to fins

Petersen discs have been attached to the fins of shark but found to work loose (Thomson, 1963) (Fig. 98). Kurata (1954) attached tags with wires around the caudal peduncle. He noted a considerable degree of skin and muscular abrasion (Fig. 99).

6.3 Loss of tags

A number of workers have noted a loss of tags under various conditions.

6.3.1 Principles affecting tag loss

Alverson and Chenoweth (1951) tested fish tags on albacore in a water tunnel. Their procedure was to increase the velocity of the water until the tags were dislodged or until the fish showed signs of tearing loose from its holder. The tests indicated that the use of Petersen or strap tags or any other tag which offered considerable resistance to the water flow could be unsatisfactory, particularly if used on fish which swim at high speeds. Plastic streamer tags appeared to be satisfactory. Strap tags such as used in the California mackerel fishery could not be dislodged but the experiment suggested that they would gradually work free.

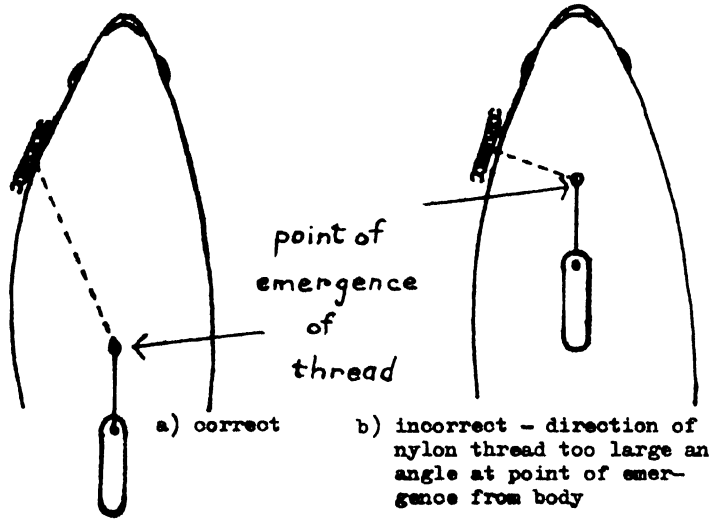

point of
emergence
of
thread
a) correct
b) incorrect - direction of nylon thread too large an angle at point of emergence from body

Fig. 96 - Ways of applying toggle attachment (Redrawn from Parrish and McPherson, 1955)

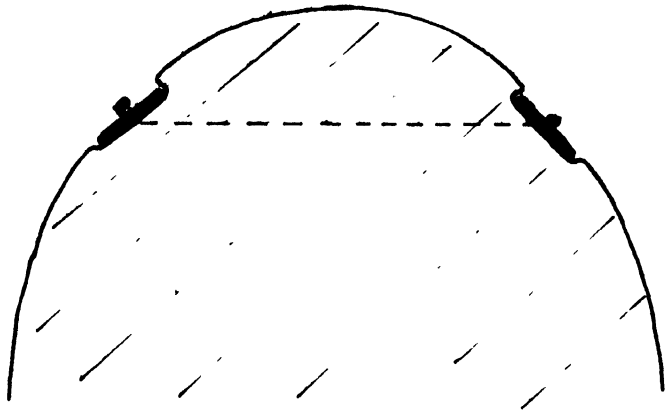


Fig. 97 - Peterson discs embedded in tissue due to growth of fish (Modified from illustration in Hartt, 1963)

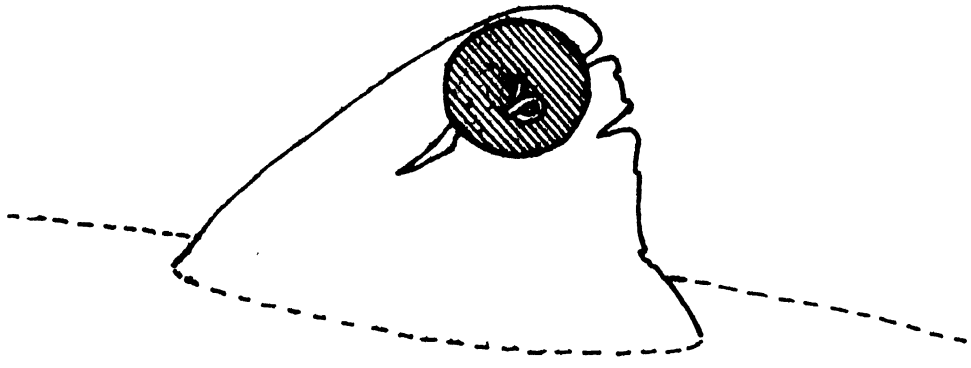


Fig. 98 - Petersen tag working loose from shark fin (Redrawn from Thomson, 1963)

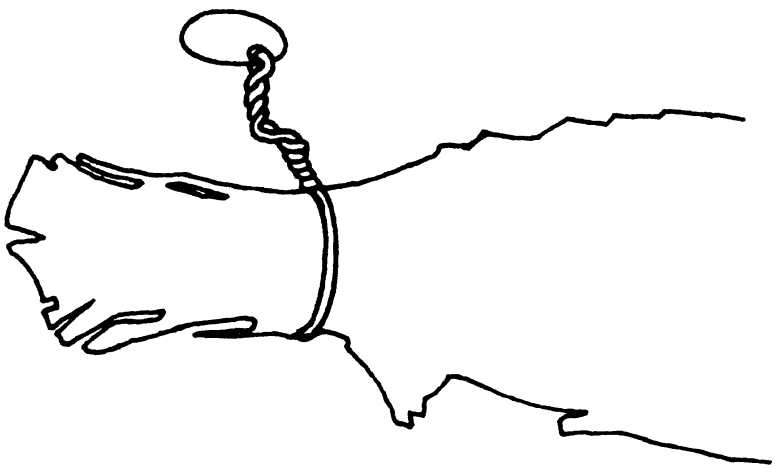


Fig. 99 - Severe caudal abrasion due to presence of caudal tag
(Redrawn from Kurata, 1954)

6.3.2 Examples (external tags)

Mills (1959) considered that tags on salmon parr could be lost by becoming entangled in the netting. Quoting Smith (1957) he remarks that predators snapped at hydrostatic tags carried by other individuals and thought that this could be a source of mortality or tag loss. Parrish and McPherson (1955), using polythene tags, thought that there could be a high incidence of tag shedding.

Van Sommern and Whitehead (1959) marked Tilapia with plastic streamer tags and considered that the loss of tags never exceeded 8%, despite repeated monthly netting and handling of the fish. They thought that in wild populations the tags were probably lifelong fixtures and that there was no evidence of selective predation on tagged fishes.

Graham (1929) gives examples of tags that were unsuccessful and lost within a relatively short time. These include a fish hook mark in which a small silver plate was riveted to a barbed silver hook attached to the operculum or dorsal musculature (Figs. 100a and b); a paper clip mark cut out of silver or nickel sheet and folded into the required shape (Fig. 100c); and a celluloid tag slotted through a hole in the operculum and pointing either vertically down or along the axis of the body (Figs. 100d and e).

Bayliff and Klima (1962) found that central Pacific anchoveta quickly shed all of the many types of external tags tied on them.

6.3.3 Examples (internal tags)

Le Cren (1954) using subcutaneous tags noted that although the marking had little effect on the survival and health of the fish, nearly 20% of the fish lost their tags.

Clark and Janssen (1945) compared shedding of internal tags inserted using either a tagging gun or the scalpel-forcep method. They concluded that tag shedding appeared to be greater among the fish tagged using the gun than among those tagged manually.

Winters (1977), working with herring during the spawning season, found that "most of the tags inserted into maturing herring were extruded with the reproductive products. On the other hand those applied to recently spent or recovering herring had had sufficient time to become attached to the internal organs and hence had a high retention rate. The results indicated that the effectiveness of internal herring tagging should be greatly improved if conducted only on recovering or spent fish".

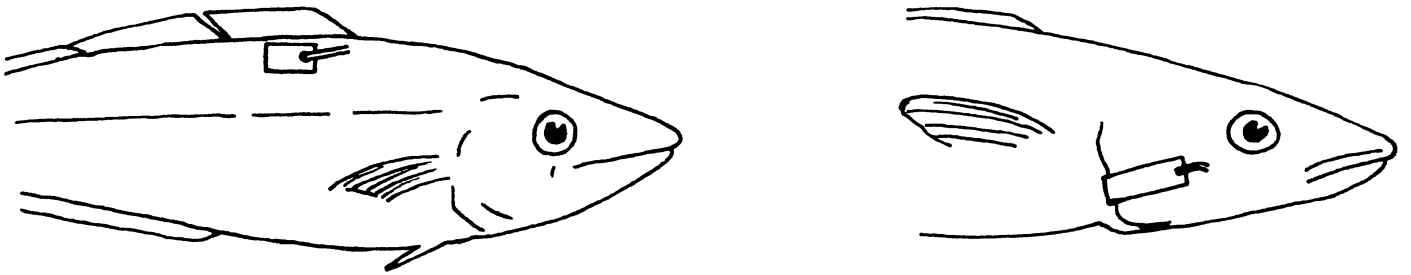
Bayliff (1966) reported an average of 33.2% of internal tags were shed by central Pacific anchoveta, almost all within the first month. After the incision had healed over, there was little or no shedding.

6.3.4 Double tagging

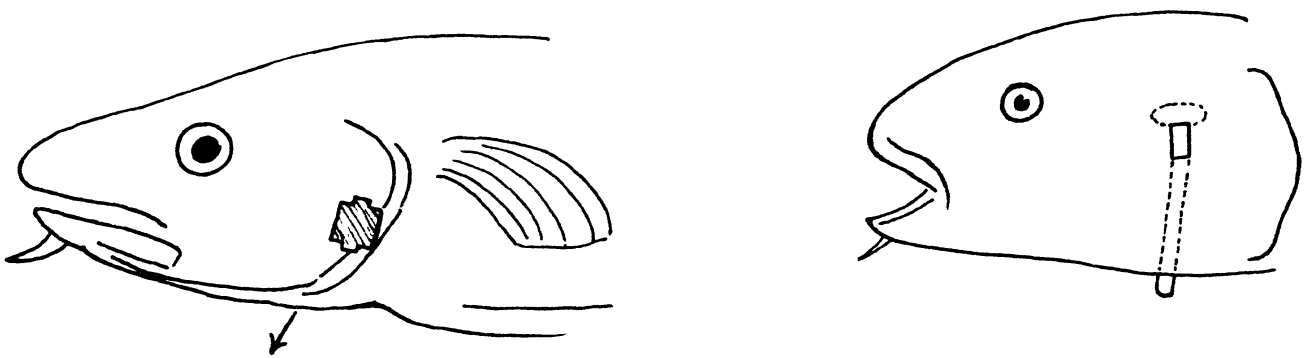
Experiments in which fish are marked with two tags can be useful for estimating the rate of tag loss. Myhre (1963), for example, describes double tagging experiments on Pacific halibut. Laurs et al. (1976) do so for North Pacific albacore. Theoretical details are given by Gulland (1963), Chapman, Fink and Bennet (1965), Bayliff and Mobrand (1972) and Beverton and Holt (1957).

6.4 Factors affecting survival

There are a number of factors affecting the survival of marked fish.



a) and b) small silver plate attached to fish by a hook



c) piece of silver or nickel folded to required shape

d) and e) celluloid dagger pushed through the operculum

Fig. 100 - Some examples of unsuccessful tags (Redrawn from Graham, 1929)

6.4.1 Changes in pressure

As already mentioned in section 2, physoclistous fish brought up from deep water are liable to suffer damage due to expansion of the swimbladder. Experiments with haddock, which are normally caught in depths of 60 m or more, show that when these are brought to the surface the swimbladder may expand without necessarily rupturing. Fish with expanded swimbladders are readily detectable since their buoyancy is affected and the fish have to expend considerable energy to prevent themselves from floating upside down on the surface. When the swimbladder is punctured, it may happen that there is only a relatively small hole in the swimbladder leaving the fish with its buoyancy unimpaired and apparently in good condition. Subsequent observations under aquarium conditions suggest that small ruptures to the swimbladder do not necessarily impair the fish and that these holes subsequently heal up. In the case of fish with ruptured swimbladders, a loss of gas from the body in the region of the vent can often be observed by divers when the fish are brought to the surface (Hislop, 1969).

The symptoms of distress of species such as redfish, which are usually caught in relatively deep water, are not necessarily confined to the extension or rupture of the swimbladder and gas in the body cavity. The eyes may protrude and the pressure of gas in the body cavity even may cause the stomach to evert through the mouth (Sandeman and Rees, 1963).

Some species, such as cod, appear to be less susceptible to the effects of pressure changes than others (McCracken, 1963).

6.4.2 Temperature

Experiments with yellowfin tuna show that the rates of recovery in different sea areas are correlated with sea surface temperatures. In those parts of the eastern Pacific where sea surface temperatures are highest comparatively few recoveries have been made. In general, the results suggest very strongly that the rate of recovery is inversely related to the sea surface temperature at the time of tagging (Schaefer et al., 1961). It is thought that mortality due to hyperactivity may be enhanced at high temperatures (see also section 6.4.4).

Barrett and Conner (1962, 1964) found that stimulation of yellowfin tuna causes levels of lactate production to become higher at higher temperatures. They conclude that a high degree of speed and skill in tagging, preferably in cold water, may minimize some of the adverse physiological effects of tagging and help to improve tag returns.

Wise (1963) concludes that, other things being equal, spring appears to be the best time of year for cod tagging. Possibly twice as high a return rate may be obtained from cod tagged at this time of year compared with taggings at other times. Wise attributed this to the lower sea surface temperatures prevailing in the spring.

6.4.3 Size of fish

There are various observations that suggest that, within species, the rate of recovery may be higher for large fish than for small. For tuna there appears to be a tendency for the recovery rate to increase with increase in length of fish at least up to a certain size (Bayliff, 1973). Williams (1963) found that the rate of return from soles greater than 30 cm in length is considerably greater than that from soles less than 30 cm in length. Sandeman and Rees (1963) report that larger redfish (i.e., those over 30 cm in length) appear better able to escape from a release cage than the smaller ones.

For some species there is no evidence of a size effect. For example, McCracken (1963) found no significant variation in the return rate of cod over a size range of 40–90 cm.

6.4.4 Activity and hyperactivity

It has been known for some time that death can occur in fishes under certain conditions following intense muscular activity. The conditions can include struggling in a live box, responding to vigorous chasing, swimming swiftly, or struggling on a fishing line. Under

these conditions death has been observed for a variety of species including salmon, striped bass, gadoid fish species and flatfish.

Although the precise cause of death is not certain, it is likely that it is due to a severe acid-based disturbance following a large accumulation of lactic acid. There appears to be a marked reduction in the ability of the heart to pump blood following severe exercise. Also both the oxygen and carbon dioxide carrying capacity of the blood is apparently altered by the accumulation of fatigue products (Black, 1958).

Barrett and Connor (1962 and 1964) investigated the blood lactic level in tunas both during tagging and various degrees of exercise. They conclude that there can be little doubt that the tagging of yellowfin and skipjack tunas results in a high rate of mortality. They conclude that this may be due in part to the severe degree of muscular activity undergone by the fish during the tagging operation. They add that these adverse conditions may persist for many hours after the actual tagging, thereby reducing the ability of the fish to feed and protect itself or respond normally to its environment. Parker, Black and Larkin (1963) consider that this factor is so important that the time taken to mark a fish should be minimized even at the expense of omitting desirable steps such as the taking of length ats.

Beverton and Bedford (1963) noted that for cod and sole, the return rate was higher from fish classed as active at the time of tagging than from fish classed as "sluggish", though the difference in classification was probably a result of earlier damage, i.e., the "sluggish" fish were those suffering from earlier "over-activity", physical bruising on the trawl, etc. Kotthaus (1963) obtained a similar result for soles.

6.4.5 Loss of scales and body fluid

There is a good deal of evidence that loss of scales can contribute to the mortality of tagged fish.

Beverton and Bedford (1963a) investigated the effect of external condition on the return rate of whiting, cod and sole. They obtained significantly higher return rates from fish whose superficial appearance was classed as good, as from those classed as poor. Good fish were those having not more than 2 cm^2 of scales missing. Those classed as poor had more than 6 cm^2 of scales missing, including relatively large rubbed patches, and damage to fin rays and a generally poor appearance. Similar results were obtained for haddock by McDermott and Livingston (1963). For cod, condition was found to be size-specific, the effects being more pronounced in the case of small fish than large. Other workers have obtained similar results for herring (Jensen, 1955; Ancellin, 1963; Parrish and McPherson, 1963).

Parrish, Blaxter and Holliday (1958) suggested that the high mortality of captured herring in sea water was a result of osmotic loss of water through the damaged epidermis when there was considerable scale loss. Holliday and Blaxter (1961) showed that this mortality could be considerably reduced by holding the herring in reduced salinity, approximately isotonic with the blood, and that in many cases fish that were distressed in sea water would recover rapidly in ⅓ concentration sea water. They considered that at least 50% of the scales should be intact before a fish could commence any degree of osmotic control, however. Similar observations have been made for salmon by Hartt (1963).

6.4.6 Mortality in holding devices and lowering cages

Beverton and Bedford (1963a), working with plaice, noted that there was a general deterioration in the condition of the survivors held on board in deck tanks, except amongst those fish that were initially classed as having very good condition. They concluded that holding plaice on board for a period of two to three days before release may actually reduce their chances of subsequent survival. The best routine procedure appeared to be the conventional one of returning the fish to the sea as soon as possible after catching and tagging them. They considered that it should be advantageous to record their condition and to take this into account when analysing subsequent recaptures.

Beverton and Bedford also investigated the effect of order of tagging on the return rate of whiting. They found that this did not have any appreciable effect when catches were small or medium sized but had a marked effect when hauls were so large that it took 4 to 5 hours to complete tagging. They noted that the return rate from the first fish tagged from large hauls was not only higher than from the last fish tagged, but also higher than from any fish caught in small or medium hauls. They concluded that the order of tagging may be critical in species such as whiting, especially when the size of haul varies considerably.

Hartt (1963), working with salmon, noted that not only was there a decline in the percentage returned with increasing time spent in deck tanks, but that the salmon held in the tanks on one side of the vessel yielded a much better return rate than those held in tanks on the other side. He considered at some length the effects of water flow, aeration, turbulence, presence of air bubbles, saturation of dissolved air in the water supply and the water flow generally.

Winters (1977) tagged Atlantic herring and considered that the fish should be held for as short a period as possible for tagging.

Dawson (1957) noted that there can be a high incidence of cannabilism amongst captured shrimps, particularly when the density is high.

Stevenson (1955) found that overcrowding of herring in impoundments prior to tagging could lead to a reduction in the recovery rate.

For some species, holding time would appear to be less critical. For example Myhre (1963) left tagged halibut for 2-week periods in live boxes, and did not observe significant tagging mortality. Hayes (1963) kept king crabs in holding boxes for up to 3 days after tagging and noted that mortality during this period was less than 1%. At the Marine Laboratory, Aberdeen, experiments have shown that fish in good condition that have been caught at sea, tagged and brought back to the laboratory tend to survive for quite considerable periods if they survive for the first few days.

It seems likely therefore that for some species, holding either before or after tagging should be minimised whereas for other species this may not be a critical factor. In any case records should be kept in such a way that the time between capture and tagging can be taken into account in later analysis, possible reduced return rates from fish tagged after some delay detected, and appropriate correction made for the reduced survival and smaller numbers effectively tagged.

6.4.7 Mortality due to predators

Mortality due to predators can be important at the time of release. For example, marine physoclistous fish may be particularly susceptible to attack by sea birds after release if their swimbladders are expanded and they cannot submerge. Seals or sea lions around the tagging vessel are another hazard to released fish in some areas.

There have been various observations suggesting that fish may be made conspicuous to predators by the presence of their tags. There would appear to be no general solution to this problem, the best tag for subsequent detection by fishermen not necessarily being the best tag for remaining inconspicuous to predators.

Small schooling fish are probably more vulnerable to predators if released singly than if released in groups.

6.4.8 Survival of fish tagged underwater

Hislop and Hemmings (1971) describe observations by divers on the survival of tagged haddock. The fish were caught by demersal trawl or Danish seine. Haddock were confined

in sea bed cages and experiments showed that the initial mortality was greater for fish that had been previously taken to the surface after capture than for fish transferred underwater from the codend to a sea bed cage. They concluded that the main factors responsible for initial mortality in the fish that had been taken to the surface were likely to be physiological shock and fatigue together with swimbladder damage. The tagging operation itself was considered to be a comparatively minor factor contributing to mortality. According to Hislop (1969), 90% of fish tagged underwater survived for the first 5 days after tagging, compared with only 19% of those tagged at the surface.

6.4.9 Size of catch

The size of catch can influence the condition of the fish (see section 6.4.6).

6.4.10 Anaesthetics

While in principle it may appear advantageous to use anaesthetics during the tagging process, there is no evidence to show that this improves the rate of return.

For example, Hartt (1963), working with salmon, used MS222 and quinaldine. This treatment rendered fish easier to handle during tagging and practically eliminated the loss of scales during the tagging operation, but a comparison of the return rates of anaesthetised and non-anaesthetized individuals showed no significant differences.

Experiments with haddock at the Marine Laboratory, Aberdeen, showed that freshly trawl-caught fish can be tagged or anaesthetized without apparent harm. However, when fish are both anaesthetised and tagged, the survival rate is noticeably smaller. It was concluded that the anaesthetic was an additional stress factor and that for trawl-caught fish its use could actually be disadvantageous. (See also section 2.3.)

7. THE PLANNING OF A MARK-RECAPTURE EXPERIMENT

A marking experiment should always have an experimental design, the details of which will be influenced to a large extent by the objectives of the experiment.

7.1 Objectives

A marking experiment should always be designed with a specific objective in mind. Principal objective and factors related to them are:

7.1.1 Movements

If the object is to investigate large-scale movements, it is important that the method of recovery is one likely to provide reliable information on the position of recapture. This means, for example, that internal tags recovered by magnetic separators in fish meal plants would not provide useful results if catches came from a large area. A better choice would be an external tag or mark capable of detection at the time of recapture.

For the study of small-scale movements, a sonic tag is likely to give the best results. Note, however, that sonic tags are relatively large compared with other tags, and therefore are only suitable for use on relatively large fish such as tuna, cod or salmon.

7.1.2 Mortality

For investigating mortality there are two liberation procedures:

In one, all the marked fish are released together at the same time. In this kind of experiment it is important to know when each fish is recovered. Recaptures can be grouped according to various time periods, but in general the more precisely each recapture time is known, the better.

An alternative procedure is to release marked individuals in groups at known intervals. With this method, recapture times are also required, but not necessarily so precisely. For example, if groups of marked animals are released at annual intervals, it may be sufficient to know in which year a fish is recaptured. With the first method, however, it is usual, although not always necessary, to know the recapture time more precisely than this.

Both methods require records of the fishing effort expended in making the recaptures in each period, preferably broken down by area.

A number of factors can bias mortality estimates from marking experiments. In particular, there is likely to be some additional mortality of marked fish, either initially, due to the process of capture, handling and marking, or subsequently, due to the presence of the mark on the fish. Loss of tags, non-reporting of marks, emigration of marked individuals away from the recapture area, can also bias the results. These factors all lead to overestimates of the mortality rate of the unmarked individuals.

7.1.3 Estimation of population size

For estimating population size, it is important that the distribution of marked and unmarked individuals be the same. If marked individuals are liberated together, they should be given time to disperse and mix with the whole untagged population before taking account of any recaptures. Alternatively, it may be better to liberate the fish in small batches over the whole area occupied by the unmarked population. Whether this is practical or not will of course depend on the area occupied by the unmarked population.

In situations where mortality is likely to be significant, it may be necessary to have an estimate of it in order to determine population size. In that case the experiment should be designed to estimate mortality as well as population size.

7.1.4 Growth and ageing

For investigating growth and ageing, the times of liberation and recapture of each fish should be known as precisely as possible.

Account should also be taken of the fact that the growth, or rate of ring formation, of a marked individual may not be the same as that of an unmarked individual. Wherever possible therefore the results obtained by tagging should be checked against observations made on unmarked individuals. When considering the growth or apparent growth during a short period after tagging, the possibilities of a check in growth due to the shock of tagging, and a post-mortem shrinkage of fish returned by commercial fishermen should be taken into account.

7.1.5 Investigation of behaviour

Care should always be taken when planning to study behaviour by a marking experiment. The behaviour of a marked individual may not be the same as that of an unmarked one. There is always the danger therefore that such experiments provide only information about the behaviour of marked animals.

7.2 Other factors to take into account

Apart from factors directly related to a specific objective, there are other factors that should be taken into account when planning an experiment.

7.2.1 Species and size of fish

The species and size of fish can influence the choice of tag.

7.2.2 Method of capture and amount of handling

Method of capture and amount of handling can be important, especially when dealing with delicate fish. For example, fish caught in very good condition may have to be anaesthetized or subdued with a cloth over the eyes (provided this is effective) or restrained in a specia holder, to prevent them from damaging themselves. Fatigued fish on the other hand often lie limply in the hand when removed from the water and hence require no special means of restrai

7.2.3 Duration of experiment

For an experiment of long duration, it is essential to choose a mark that is likely to remain visible and on the fish for as long as possible. For short duration experiments this may not be so important.

7.2.4 Numbers to be marked

It should be determined in advance how many recaptures will be needed, and that enough fish can in fact be tagged and released to attain this target. For ways of determining the number needed see Robson and Regier (1964), Davis (1964) and Cormack (1969).

7.2.5 Number of people available

Clark and Janssen (1945), working with sardines, recorded the percentage of tags recovered from each batch of 100 sardines. They found a decline in the proportion of tags recovered from each succeeding 100 fish tagged. They thought that this was probably due to operator fatigue. Sufficient time and manpower must be provided to mark the required number of animals properly.

7.2.6 Skill required

Marr (1963) considers that tagging mortality is directly proportional to the time taken in tagging. With experience, individual marking speeds tend to increase, reducing the time required for marking and increasing return rates.

7.2.7 Method of recovery and publicity

The mark to be used should be chosen so as to facilitate the detection and reporting of marked fish by fishermen or others. In most cases the rate of recovery can be further improved by publicity. If publicity is needed, this should be arranged in good time before the start of the experiment. The address to which tags should be sent, should be printed on each tag.

7.3 Requirements of an ideal fish mark

According to Arnold (1966) an ideal fish mark should have the following characteristics

(1) It should be retained in an essentially unaltered condition for the lifetime of the fish regardless of the age at which it is applied.

(2) It should have absolutely no effect on the fish's behaviour, reproduction, life-span, growth, movement, or vulnerability to predation and other external factors.

(3) It should not tangle in vegetation or nets of any kind.

(4) It should be inexpensive and easily purchased or fabricated.

(5) It should be usable on any size of fish without significant alteration.

(6) It should not be found in nature nor should it be possible to confuse it with any other mark, natural or artificial.

(7) It should be easily applicable to fish in the field without the need for an anaesthetic.

(8) It should be easily detectable in the field by untrained personnel or the public.

(9) If the marked fish is preserved as a scientific specimen or for later examination, the mark should not be affected by the preservative.

(10) There should be enough possible variations of the mark so that many individuals or many small groups can be identified separately.

(11) The marking substance should not present any health or safety hazard to either the biologist, the fish or the public.

(12) The mark should not cause adverse public relations by spoiling edible parts of the fish, detracting from the aesthetic appearance of the fish or in any other way.

Arnold goes on to add that no marking device or agent known at present satisfies more than a few of these criteria. Until demonstrated otherwise, marks must be assumed to interfere with the activity of the fish and may interfere with its health, particularly (in the case of tags) by providing an entrance for pathogens. Most tags cannot be used on very small fish, (i.e., smaller than 8 or 10 cm).

7.4 Information to record when marking

7.4.1 The size of the animal

For some experiments (e.g., growth determination) the size of the animal must be determined when marking. For other experiments, measurements should only be made if the extra handling time is not likely to influence the likelihood of survival. Whether it is worth doing this will then depend on the number of people available and whether the species is a delicate or a hardy one.

7.4.2 Fish condition

Beverton and Bedford (1963) have shown that return rates can be influenced by the condition of the fish when tagging. It is useful therefore to note fish condition at the time of marking in order to take account of this when analysing the results.

7.4.3 Duration of the tagging operation

If large numbers of animals for marking are caught at the same time, it may be necessary to keep them for some time in a holding container. This may influence the likelihood of subsequent recapture and to allow for this the duration of holding time should be recorded.

7.4.4 Water temperature

Water temperature can influence the survival of marked fish. The temperature at the time of marking should therefore be recorded.

7.5 Ancillary experiments

In addition to the primary marking experiment, other experiments may be necessary to provide additional information. For example:

7.5.1 Double tagging

Rates of tag shedding can be investigated by tagging a proportion of animals with two tags. Details of methods of analysis are given by Gulland (1963), Chapman, Fink and Bennett (1965), Bayliff and Mobrand (1972) and Beverton and Holt (1957).

7.5.2 "Seeding" experiments

To investigate non-reporting of marks, marked fish can be planted or "seeded" at various points in the recovery process (see sections 5.1 and 5.5). Where seeding can readily be done (e.g., seeding magnetic tags in fish meal plants) it should definitely be done; if there are practical difficulties in a realistic trial, e.g., everyone is fully aware of what is going on, other methods of estimating tag return rates should be tried.

7.6 When not to mark

In principle a marking experiment can provide a great deal of information about a stock of fish or other animals, but there are several practical problems that must be solved for the experiment to succeed. Once the specific objectives of the experiment have been decided, it must be reasonably assured that:

(1) There are means for capturing animals in good condition.

(2) The animals can be marked and released in such a way that a fair number will survive.

(3) The chosen mark will remain on the animals for a sufficient period of time and be readily detectable when the animals are recaptured.

(4) Sufficient staff and ship time are available to mark enough animals to provide the required number of returns.

(5) Fishermen and others who come across marked animals will report them.

(6) If necessary, rates of tagging mortality, tag loss and non-reporting can be estimated.

(7) Final analysis of the return data will provide sufficiently accurate and precise estimates to achieve the primary objectives of the experiment.

If any of these prerequisites cannot be satisfied, there will be no point in trying to carry out the experiment. At best, it would be a waste of time, and at worst it could tend to discredit the agency conducting the experiment in the eyes of the government, industry and public.

This does not mean that marking experiments should be avoided forever because of unsolved incidental problems, but rather that these problems should be solved by experimental and pilot work before a full-scale experiment is attempted.

8. SUPPLIERS OF FISH MARKS AND MARKING EQUIPMENT

This list below is based on replies to letters of inquiry sent to fishery research laboratories in countries with substantial marking programmes, and to manufacturers listed in the latest ICES catalogue of fish marks (ICES, 1965). It does not include firms that offer only the materials used in making marks (e.g., polyurethane tubing, silver wire, nylon thread), and certainly is not a complete listing of firms that offer finished marking products. It should nonetheless be useful to people working in places where any information on suppliers is difficult to obtain. (N.B.: In publishing this list FAO does not recommend in favour of the suppliers named, or endorse their products in any way. Neither does it commend against any suppliers not named. All inquiries concerning products, orders, price and terms should be addressed to the suppliers themselves.)

In some countries (e.g., Japan, Poland) fishery agencies usually produce tags in their own workshops, or have tags made to order by local firms of metal or plastic fabricators, rather than buying stock items from commercial suppliers. If the tag is a simple one, such as a Petersen disc, this can be easier and cheaper than ordering from a supplier. On the other hand, stock items obtained from a reputable firm will normally be made of the proper materials to a proven design, and since the cost of marks is usually a very small part of the total cost of a marking experiment, it will not be worthwhile to achieve small savings here at the risk of having the whole programme frustrated by some unnoticed defect in the mark or marking equipment (e.g., rough edges on internal tags).

Canada

A.R. Monteith Ltd. 216 Wharton Glen Ave. Mississauga, Ontario	Fluorescent grits for spray marking
Arnold Nasco, Ltd. Guelph, Ontario	Freeze branding and hot iron branding equipment; jumbo rototags; strap tags

Federal Republic of Germany

Firma Amko GmbH Marktstätte 22 7750 Konstanz	Anchor tags
Firma Christian Saar EZONA - Etikettenfabrik Postfach 1227 4244 Elten	Anchor tags
Firma Heinrich Rathjen Brunckhorstweg 19 2000 Hamburg 54	Labelled plastic tags

Ireland

Argus Manufacturing Co., Ltd. 61 Lower Camden St. Dublin 1	Anchor tags and tagging guns
Dalton Supplies Leeson Close Dublin 2	Jumbo rototags

Fine Art Plastics Ltd. Synge Lane Synge Street Dublin 8	Flat tag with message in laminated plastic
Kaiyosokki Co.,Ltd. Chuo Building, 2-12 Sakuma-cho Kanda, Chiyodaku Tokyo 101	Dart tags (for tuna)
Norway	
A/S Protector Nesttunveien 116 5050 Nesttun	Disc tags
Bergen Nautik P.O. Box 1231 5001 Bergen	Internal magnetic tags and applicator; external flat plastic tags
Institute of Marine Research P.O. Box 1870-72 5011 Bergen-Nordnes	Alcathene tags
Li-Bo Tekniske A/S Oraveien 5/7 1600 Fredrikstad	Lea hydrostatic tags
Sweden	
AB L. Fägersten Varholmsgatan 5 41474 Göteborg	Lea hydrostatic tags
United Kingdom	
Charles Neal and Sons The print 30/32 Friern Park North Finchley London N12 9DA	Petersen discs
Ketchum Manufacturing Co. Tadworth, Surrey KT20 5RE	Anodized aluminum strap tags (freshwater only)
Reliance Nameplates Ltd. Cambridge Road Twickenham, Middlesex TW1 2HW	PVC crab tags (disc)
Transatlantic Plastics Ltd. 45 Victoria Road Surbiton, Surrey	Plastic flat tags

United States of America

Floy Tag & Manufacturing, Inc. P.O. Box 5357 Seattle, Washington 98105	Dart tags, spaghetti tags (tying or locking), anchor tags, streamer tags, Petersen tags; applicators
Howitt Plastics Co. P.O. Box 162 Molalla, Oregon 97038	Plastic discs for Petersen tags; subcutaneous plastic tags
Lee Mark Co. 635 Marina Vista Martinez, California 94553	Vinyl ink
Matteson, Coleman and Bell Norwood, Ohio 45212	Biological stains (Bismarck Brown Y. and Rhodamine B.O.)
National Band and Tag Co. 721 York St. Newport, Kentucky 41072	Monel strap tags, magnetic internal tags, vinyl subcutaneous tags
Northwest Marine Technology Shaw Island, Washington 98286	Magnetic wire nose tags and related equipment
Pilgrim Plastic Products Co. 278 Babcock St. Boston, Massachusetts 02215	Internal tags; messages printed on fine white plastic for capsule tags
Salt Lake Stamp Co. 380 West Second South Salt Lake City, Utah 84101	Circular strap tags
Telectronic Laboratories, Inc. P.O. Box 971 El Monte, California 91731	Vinyl tubing (for spaghetti tags; the firm will print on the tubing)

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